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TABLETS

OF

ANATOMY AND PHYSIOLOGY

BY

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Being a Synopsis of Demonstrations given in the Westminster Hospital Medical School in the years 1871, -72, -73, -74, & -75.

WITH AN APPENDIX

CONTAINING MOST OF THE NEW DISCOVERIES OF IMPORTANCE MADE KNOWN UP TO THE DATE OF PUBLICATION.

PHYSIOLOGY COMPLETE.

SECOND EDITION.

"The schemes of any of the arts or sciences may be analysed in a sort of skeleton, and represented upon tables, with the various dependencies and connections of the several parts and subjects that belong to them; and the frequent review of these abstracts and epitomes would tend much to imprint them on the brain, when they have been once well learned; this would keep those learned traces always open, and assist the weakness of a labouring memory."

ISAAC WATTS, D.D.,
ON "THE IMPROVEMENT OF THE MIND."

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ERRATUM.

PAGE 57, 1st line, *for* "**BLOODLESS GLANDS**" read "**DUCTLESS GLANDS.**"

PREFACE TO THE FIRST EDITION.

(Anatomy only.)

In a Learner's point of view Scientific facts may, the Author thinks, be divided into those which are daily met with by the Student, and which soon become familiar to him, and those which are learned with considerable pains and afterwards easily forgotten, and which require to be constantly recalled to the mind.

The Author has endeavoured to deal with the latter class of facts only. What every one knows, who has at all studied Medicine, he has purposely left out. Greater condensation is thus obtained. To the non-medical reader the Tablets may appear disconnected, and the descriptions they contain (if descriptions they may be called) may seem dry and naked. The Author believes that the Student will easily supply the links, and give life and shape to the skeleton sketches.

This book is intended neither for the idle, nor for absolute beginners. The idle will find that it contains more details than they will care to master, and that its brevity demands more mental application than would be agreeable to any one, whose mind has not been trained to close study.

Beginners, however, who mean to work, may, after attending a lecture, or reading up in one of the Standard Authors a region they have just been dissecting, advantageously revise the subject in the Tablets; and these partial revisions will be found to fix the main points in the mind, and to facilitate the more important revisional effort, which, even the first year's student is usually called upon to make, whenever his lecturer has finished describing a part, or he himself has finished dissecting one.

The more or less advanced Students, who are doing, or have done, their work honestly and conscientiously, are the ones the Author has had mainly in view.

16, Woburn Place, Russell Square,

September, 1875.

PREFACE TO THE SECOND EDITION (1878).

(Anatomy and Physiology.)

In the present Edition, only those pages have been recast, which were considerably out of date; the others, when requiring alteration, have simply been supplemented by an *Appendix*, which has been incorporated with the work, as far, at least, as could well be done without involving considerable book-binder's labour. The pages of this Appendix have been marked 8A, 8B, 12A, 12B, 12C, etc., in correspondence with the pages they are intended to supplement or correct; and its headings have been *underlined red*, to call attention to the new matter.

A fresh Appendix *containing new discoveries of importance* will be published every two or three years. And every succeeding Appendix will be issued both separately and incorporated with the work.

The present Appendix to the Anatomy refers to the Viscera, & to the Organs of the Senses. It has been inserted after pages 290, & 360. Dr. Gowers' new description of the Gray Matter of the Cerebellum, and the views of Lockhart Clarke, Stilling, and others on the cranial nerves, etc., will also be found on pages 213, 230, & 250, of the text. Descriptions of the Thymus & Thyroid Bodies and Suprarenal Capsules have been added; also a careful description of the Teeth.

In the Physiology, new matter is more abundant: The Appendix numbers forty pages. Twelve supplement Circulation; four, Respiration; eight, Digestion; four, the General Development of the Embryo; eight, the Development of the Organs; and four are included under the heading "Addenda." – The two aspects of Physiology, the old & the new, are thus, to a certain extent, placed side by side. The latter parts of the work,—Nervous System, the Senses, and the greater part of Embryology,—having been re-written very recently, are not, for the present, supplemented.

The Embryology will be found fairly complete & up to date. Both the older & the more modern views have been presented with respect to the Pharynx, Œsophagus, & Respiratory Tract, and with respect to the questions arising out of the disputed homologies of the Genital Ducts. A few divisions have been introduced into the study of some of the subjects.

The History of the development of the Bones & Teeth concludes the volume; – the former subject being divided into two parts, *Skeletal Matrix*, and *Ossification of the Individual Bones.*

The diagrams representing the development of the veins are after those of Dr. Dalton of New York, who has treated the subject most skilfully & completely.* They have been engraved by Mr. W. Gibbs of Fleet Street.

Histology & chemical physiology will be treated in a separate volume.

ANATOMY & PHYSIOLOGY *COMPLETE* – By this phrase it is simply meant that all the subjects have been treated, which appeared susceptible of being treated *advantageously* in the Tabular form: – "*In a Learner's point of view, Scientific facts may be divided into those which are daily met with by the Student, and which soon become familiar to him, and those which are learned with considerable pains & afterwards easily forgotten, and which require to be constantly recalled to the mind. The Author has endeavoured to deal with the* LATTER CLASS OF FACTS ONLY." (V. Preface to the First Edition).

* J. C. DALTON – Treatise of Human Physiology, Philadelphia, 1871, & 76.

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ADVICE TO STUDENTS.

The principal rules of the art of learning are to classify, to condense, and to proportion, according to their relative importance, the attention to be given to the facts that are to be retained.

Classify.—Group things that are alike; thus, in learning one, several will be acquired.

Condense.—The more concise the wording is, the more facts can be gone over in a given time, and the better they can be remembered. A firm grasp of the facts is what is wanted first; erudition may be courted afterwards.

Proportion according to their relative importance the attention to be given to the facts that are to be retained. The headings & subheads should be mastered first; then, in succession, the divisions, the sub-divisions, the principal points, the minor points, the noteworthy details, the minutiæ.

The Tablets are intended to assist the Student in carrying out these rules:

The *grouping* and the *condensing* are done for him to a considerable extent.

The arrangement adopted will further induce him, it is hoped, to proportion his attention rightly: – The Tablets, especially those on Anatomy, show at a glance the general outline of the subject they treat of; this outline should be studied first, and thoroughly understood and mastered before the Student goes any further. *This is of primary importance for the successful use of the Tablets,* which, the Author would remind the Student, are intended simply to assist him in reading the standard Authors with greater profit and ease, *not to take the place of any other work.*

To

WILLIAM SCOVELL SAVORY, Esq., F.R.S.,

SURGEON TO, AND LECTURER ON SURGERY AT, ST. BARTHOLOMEW'S HOSPITAL;

LATE PROFESSOR OF COMPARATIVE ANATOMY AND PHYSIOLOGY

AT THE ROYAL COLLEGE OF SURGEONS; MEMBER OF

THE COURT OF EXAMINERS OF THE

SAID COLLEGE.

Sir,

As an expression of my respect for your efforts in promoting the study of Physiology among Students, and as a token of my gratitude for past kindness, I beg to dedicate to you these unpretending little Tablets on Physiology.

I am,

Sir,

Yours very truly,

THOMAS COOKE.

Woburn Place, April, 1873.

P.

CIRCULATION.

PHYSICAL PROPERTIES of the BLOOD.

The blood is a *thick & heavy* fluid of a *bright scarlet* colour, when flowing from an artery, and of a *deep purple*, or nearly black colour, when flowing from a vein.

Its average *temperature* is *about* 100° *or* 102°, but is not the same all over the body, for the blood is cooled when passing through the capillaries of the skin and is slightly warmed when passing through large & active glands such as the liver.

Its *specific gravity* varies *from* 1050 *to* 1059, the average being 1055, the gravity of water being reckoned at 1000.

The blood is slightly *alkaline* in all animals and under all circumstances. The supposed exception in the case of menstrual blood is due to the admixture of acid mucus from the uterus and vagina.

The blood emits an *odour* similar to, but fainter than, that emitted by the animal itself. This odour is principally *due to a volatile fatty acid*, and it may be set free, even when the blood is dried up, by adding to it small quantities of a mixture of equal parts of sulphuric acid & water.

Quantity of Blood in the Body.

The whole of the blood weighs normally in man *about* 1-8*th or* 1-10*th of the weight of the body.* The quantity of the blood varies, however, considerably according to the amount of food & drink recently taken, and to the quantity of water given off; it may be reduced to nearly half by long fasting.

The quantity of blood in the body *cannot be ascertained* with any degree of precision *by simply bleeding an animal to death and measuring the blood that escapes*, for on the one hand a large amount of blood would then remain in the vessels, and, on the other hand, if death ensue but slowly, large quantities of fluid would be absorbed from the tissues to refill the emptying vessels, and would add considerably to the apparent amount of the blood that would be drawn.

Leaving aside the lengthy calculations of Vierordt, based upon uncertain estimates of the amount of blood expelled from the left ventricle at each beat of the heart, & of the number of beats necessary to complete the round of the circulation, there remain *two principal methods of ascertaining the quantity of the blood* in the body :—

1. Weclker *bleeds an animal rapidly to death*, and measures the blood which escapes. He then *washes out the vessels* by abundant injections of water, and calculates the additional quantity of blood which then flows out, mixed with water, by comparing the colour of the mixture with that of other mixtures made in known proportions ;

2. Valentin *injects a known quantity of water;* Blake, *a certain quantity of some saline substance*, such as sulphate of aluminium, which is not found in the blood, and which is of easy detection. The *calculation* is then founded upon the *diminution of the specific gravity* of the blood, or upon the *proportion of the saline substance diffused* in a measured quantity of the fluid. This latter method may, however, be objected to, on the ground of the probably unequal dilution of the blood, or of the probably unequal diffusion of the saline substance through its mass, unless a considerable time he allowed to elapse between the injection and the collecting of the samples of blood, upon the modified condition of which blood the calculation is to be based; but then the result would likewise be vitiated even to a greater extent, by the passage into the tissues, of an unascertainable amount of the water or of the salt used in the experiment.

For the *most accurate estimate* we have of the total quantity of the blood in the human body we are indebted to Weber & Lehmann. They had the opportunity of *weighing, before & after decapitation, two criminals* who had been condemned to death. The difference in the weight represented the weight of the blood that had escaped. The quantity of blood remaining in the head & trunk was calculated by Welker's method.

STRUCTURAL CHARACTERS of the BLOOD.

Structurally the blood consists of a colourless fluid, *liquor sanguinis, or plasma, of blood and lymph corpuscles*, of more or less numerous *albuminous granules & fatty particles*, similar to those found in the lymph and chyle; also, during the height of digestion, of a few *exceedingly minute oil globules*, like those which constitute the molecular base of the chyle.

Red Blood Corpuscles or Blood Cells.

Human red blood corpuscles as they circulate in the vessels are *minute flattened or slightly biconcave discs;* but they swell out through endosmosis, *& become convex when the blood is diluted* with water, and *shrink* & assume various irregular forms, *when salt, syrup*, or any other substance *is added* which increases the density of the blood. They are elastic, and admit of compression & elongation, in adaptation to the small diameter of the lesser capillaries. Their *diameter* varies *from* 1-3000*th to* 1-4000*th of an inch.*

They are now *believed to be homogeneous in structure*, the only difference between their several parts being, that their external layers are dense & firm, while their internal substance more or less approaches the fluid state. They have *no nuclei;* while they remain concave, however, the *appearance of a central spot*, due to unequal refraction, is perceived *in their thinner central portion*, and is either brighter or darker than the border, according as it is viewed in or out of focus.

A peculiar property manifested by the red blood corpuscles, is their *tendency, when the blood is at rest, to adhere in the shape of rolls, columns, or rouleaux*, like piles of coins, which latter soon join together & form a kind of network. This tendency to adhere is increased in inflammatory diseases; it partly explains the formation of the buffy coat, for the more the blood corpuscles are clustered together, the more rapidly they sink to the bottom.

Chemically the red globules consist of a delicate colourless *stroma* very abundantly infiltrated with a red *colouring matter*. The *stroma* consists of a nitrogenous proximate principle, *protagon*, combined with a modification of globulin termed *paraglobulin or fibrinoplastin* (Hoppe-Seyler, C. Shmidt). The *colouring matter* is a nitrogenous crystalisable substance, *hæmoglobin* (Hoppe-Seyler) *or cruorin* (Stokes), capable of absorbing oxygen in the lungs and of readily giving it up in the capillaries. The red globules also contain fatty matters, among which cholesterin, and salts, chiefly phosphates of potash, soda, & lime (Vide Tablets on Animal Chemistry).

White Corpuscles

Are spheroidal nucleated cells, *about* 1-2500*th of an inch* in diameter, and of a greyish pearly colour. They present a finely *granulated surface, granular contents*, and a simple or compound *nucleus*, which is clearly brought into view by the action of dilute acetic acid, the remainder of the cell then becoming transparent. It is *doubtful whether* they are surrounded by *any true cell-wall.*

They are very similar in appearance to the corpuscles of the lymph or chyle; but they differ from them chemically, for the latter are but very slightly acted upon by acetic acid.

A most remarkable property which the white corpuscles have recently been shown to possess in common with the amœba (Von Recklinghausen, Waller, Cohnheim), is their capability of *assuming*, spontaneously, *different forms*, and of *enclosing milk-globules*, or *particles of colouring matter* or of carbon; of *sending out processes in different directions* and subsequently *withdrawing them;* of *adhering to the walls of the blood-vessels, pushing processes through them*, and then *following these processes into the surrounding tissues*, in which they accumulate in great numbers, in any part of the body that has been irritated.

The average proportion of the white corpuscles to the red ones is *about* 1 *in* 400 *or* 500; but the relative number of the white corpuscles is very variable, being much increased after a meal and greatly diminished by fasting.

COAGULATION of the BLOOD.

When drawn from the body, and left at rest, the blood *coagulates in about* 10 *minutes.* The *clot* gradually *contracts* and becomes firmer, while a transparent yellowish fluid, the *serum, oozes from its surface,* and is soon abundant enough for the clot to float therein.

When examined with the microscope the clot is seen to *consist of solidified fibrin,* in the shape of minute fibrillæ, between the meshes of which the *red globules* are joined together in piles, columns, or "rouleaux;" the *white globules* are scattered here and there.

The *explanation* given of the change, until lately, *was this: the liquor sanguinis consists of serum holding fibrin in solution; the fibrin has a peculiar tendency to coagulate when at rest, & to contract; while coagulating, it entangles in its meshes the blood & lymph corpuscles and the serum; by its subsequent contraction the serum is pressed out of the clot.*

The *foregoing explanation* of the coagulation of the blood is, however, *no longer received* in its integrity; *indeed, the very existence of fluid fibrin in the blood is now disbelieved in, if not disproved.* Schmidt & Dr. Buchanan, of Glasgow, have shown that the addition of blood serum, or of red blood corpuscles to, or the contact of muscular or nervous tissue or of skin with, any serous effusion, or the admixture of serous effusions from different parts of the body, gives rise speedily to the formation of a clot. Thus fluids which have themselves little or no tendency to coagulate, can be made to produce a clot apparently identical with the blood-clot, by the simple addition of fluids which will not themselves coagulate, or of solids which are not known to contain fibrin. Schmidt supposes that the *formation of the fibrin of the clot* is *due to the union during coagulation, of two substances chemically very similar,* which he calls respectively the *fibrinoplastic & fibrinogenous,* the former of which may be obtained from almost all the tissues & fluids of the body, and is believed to be identical with the paraglobulin of the red corpuscles. The real cause of the coagulation of the blood is still, however, a mystery.

In *inflammatory diseases* & in *low constitutional states,* a layer of white clot, the "*buffy coat,*" forms on the top of the red clot and soon becomes concave or cupped on its surface. The inflammatory clot also shrinks more than usual and becomes very firm and tough, which is due to its containing a large amount of fibrin; in the case of cachectic & anæmic persons the clot is large, loose, & soft.

The *white clot* is *due to* the *partial sinking of the red blood corpuscles before coagulation takes place,* and to the inclusion in the upper part of the clot of the white or lymph corpuscles only, which are much lighter than the red ones and incline to float. This sinking of the red corpuscles occurs in inflammatory diseases and in low constitutional states, because the corpuscles then manifest an increased tendency to coalesce in columns or "rouleaux," in which condition their rate of sinking becomes greater; in inflammatory diseases the blood also coagulates less rapidly, so that the corpuscles are allowed more time to subside before they are arrested by the formation of the clot. The *absence of the red corpuscles* from the upper layers of the clot, *explains* both their *pale yellowish or greenish hue, and* also their *greater contraction & the concave or cupped shape of the surface of the clot.* The greater or less amount of fibrin contained in the blood, or formed at the time of coagulation, explains the greater or less contraction of the mass of the clot and its variable consistency.

Coagulation is hastened by rest, moderate warmth, the contact of foreign bodies or rough surfaces, slight dilution with water, and by exposure to the air, as, for instance, when the blood escapes slowly from a small artery or vein and is collected in a shallow vessel. It *is retarded by* slight agitation, cold, contact with smooth surfaces, the addition of ammonia, of alkaline or earthy salts, or of the narcotic & sedative alkaloids, the exclusion of air, as, for instance, when the blood escapes rapidly from a large artery or vein and is collected in deep or closed vessels, or when oil is poured on its surface; it is retarded also in all inflammatory states of the system.

The *serum,* or that part of the blood which remains fluid after the formation of the clot, is *viscid, yellow, & alkaline,* and contains all the constituents of the blood, except the globules and the fibrin. *Its abundance depends on the degree of contraction of the clot.* Being very rich in albumen it *coagulates, when heated,* to such an extent that it is transformed almost entirely into a white jelly-like mass. The small portion of the serum which then remains uncoagulated is termed "*serosity.*"

CHEMICAL COMPOSITION of the BLOOD.

The principal constituents of the blood are *water, albumen, fibrin, red globules, fatty and extractive matters, salts, & gases.* The relative proportion of some of these constituents may vary considerably, but the average composition of the blood as a whole is pretty constant.

Water.—*From* 700 *to* 800 *parts in* 1000.—Its *deficiency* is indicated by a sensation of *thirst,* which becomes more & more urgent as the deficiency increases. *When it is in excess,* it is rapidly *excreted in the shape of sweat & urine.* Thus, uniformity is maintained in the density of the blood, and in the fulness or tension of the vessels, and, consequently, in the rate of exudation from the vessels into the tissues, & in the rate of absorption from the tissues into the blood.

Albumen.—*From* 60 *to* 70 *parts in* 1000.—Is probably *in* a state of *combination with soda, or with the tribasic phosphate of soda,* which assist in keeping it dissolved.

Fibrin.—*From* 2 *to* 3 *parts in* 1000.—The proportion cannot, however, be very accurately ascertained, as in analyses fibrin cannot be separated from the white globules. Is much *increased in inflammatory diseases,* but, as in such cases, the white globules are much increased also, it is probable that the apparent increase of the fibrin is partly due to its being weighed along with the white globules.

Red Globules, containing *Protagon, Paraglobulin or Fibrino-plastin, Hæmoglobin or Cruorin,* and also *fatty matters & Salts.*—130 *parts* (dried) *in* 1000.—The quantity of red globules is *increased in plethora* and much *diminished in anemia & chlorosis,* in which latter state the globules have been found reduced to the proportion of 60, 50, or even 27 parts in a 1000 (Andral & Gavarret).

Fatty Matters.—*Average proportion,* 1½ *parts in* 1000—Consist of cholesterin, cerebrin, serolin, the phosphorised fat of the brain, margaric, and oleic acids, and of a volatile fatty acid, to which the odour of the blood is mainly due. They are subject to great variations in quantity, their proportion being *much increased after meals,* when the fatty particles of the chyle are added to the blood.

Extractive Matters.—*About* 6 *parts in* 1000.—The most important are *kreatin, kreatinin,* sugar, lactic acid, casein, *urea, uric acid,* ammonia, and colouring & odoriferous matters.

Salts.—6 parts in 1000.—The salt found in the blood in by far the largest proportion is the *chloride of sodium.* Among the salts of special interest are the *carbonate and phosphate* and the *tribasic phosphate of soda,* which *give rise to the alkalinity of the blood* and *preserve the fluidity of its albumen.* These salts have the property of *absorbing large quantities of carbonic acid gas, and of readily giving it off* when agitated in atmospheric air, and it is believed by Liebig that the *carbonic acid gas of the blood* is principally *combined with them.*

Gases.—100 *volumes of blood contain, collectively, from* 40 *to* 50 *volumes of oxygen, carbonic acid, and nitrogen,* the mean relative proportions of which are about as 4, 12, and 1. Arterial blood contains, however, more oxygen & less carbonic acid than venous blood. *The carbonic acid & the oxygen are partly free and partly in a state of weak chemical combination, the carbonic acid being combined with the carbonate & phosphate and the tribasic phosphate of soda, the oxygen being chiefly absorbed by the red globules, and being combined with the hæmoglobin or cruorin,* which has been shown by Hoppe-Seyler and Professor Stokes to exist in two states of oxidation corresponding to the scarlet & purple tints of arterial & venous blood.

THE ACTION of the HEART.

The *whole heart* is *relaxed & passive immediately after its beat* against the side of the chest.

During the period of repose or "*pause*," the auricles gradually fill, and a portion of the blood passes through them into the ventricles.

When the *auricles* are distended they *contract*, propelling nearly the whole of their blood into the ventricles.

The contraction, or *systole, of the auricles* is of very *short* duration; it *commences at the orifices of the great veins*, and is propagated towards the auriculo-ventricular openings, the auricular appendices being the last to contract. The reflux of the blood into the veins is thus checked, as it is also by the simultaneous contraction of the muscular coats of the veins, and, with regard to the right side of the heart, by the Eustachian & Thebesian valves, & by the valves near the point of junction of the internal jugular & subclavian veins; a small quantity of blood does, however, regurgitate.

The *ventricles, on being distended, immediately contract*, so immediately, indeed, that no interval can be perceived between their contraction and that of the auricles, the two concurring "in such wise that but one motion is apparent" (Harvey).

The *ventricles contract slowly*, and empty themselves completely. *During their contraction they rotate screw-wise to the right* on account of the spiral arrangement of their superficial fibres, *bulge out*, and *tilt forwards the apex & lower part of the anterior surface of the heart*, producing the well-known impulse of the latter against the side of the chest.—The force with which the blood is propelled into the aorta by the left ventricle is calculated to be equal to about 4 lbs., and the force with which it is propelled into the pulmonary artery by the right ventricle, is calculated to be equal to about 2 lbs. The force of the auricular contractions cannot be measured.

The *pause* or the period of relaxation, during which the cavities of the heart are again filling, *recommences for the auricles, during the contraction of the ventricles*, and *for the whole of the heart, immediately after such contraction.*—The cavities of the heart are now no longer believed to dilate actively; their diastole, though taking place spontaneously, is nevertheless a mere passive phenomenon, due simply to the relaxation of the previously contracted muscular walls.

Action of the Valves of the Heart.

The *mitral and tricuspid valves* close the auriculo-ventricular openings during the contraction of the ventricles, and prevent regurgitation from the ventricles into the auricles & great veins. The semilunar valves close immediately after such contraction and prevent regurgitation from the arteries into the ventricles.

The *closure of the tricuspid valve* is *said*, however, *to be imperfect, and to allow of a certain degree of regurgitation during violent exercise, and also when the circulation through the lungs is impeded*, a pulsation synchronous with the beat of the heart being then observable in the jugular veins. *Over-distention of the cavities of the heart & of the capillaries of the lungs is prevented by* this "*safety valve action*" as it is sometimes called.

The auriculo-ventricular valves are closed by the pressure of the blood in the contracting ventricles, their elevation being aided by the action of the elastic tissues which they contain. The *eversion* of these valves is *prevented by the chordæ tendineæ*, which are kept tense by the contraction of the musculi papillares, which contraction takes place simultaneously with that of the walls of the ventricles.

The *semilunar valves* are thrust asunder by the impetus of the blood outflowing from the ventricles.—The lateral pressure of the blood propelled into the arteries distends their elastic walls, but it does not distend, or at least it does not distend in an equal degree, the unyielding valves and the rings to which they are attached. *Three pouches, the sinuses of Valsalva, are* thus *formed behind the valves, while the valves themselves are drawn inwards towards the centre of the artery*, and are thus favourably disposed to be pressed down and closed, as soon as the ventricles cease to contract and the dilated arteries are able to recoil. The *pressure of the blood in the recoiling arteries*, as has been shown by Mr. Savory, is *not sustained by the valves alone, but also by the thick upper edge of the ventricles*, upon which the pouches of the distended artery & the outer part of the semilunar valves repose. The *margins of the valves* meet in three converging lines, along which they *come in contact* with each other, *not only by their edges but also by the ventricular surface of the lunulæ.* The *corpora Arantii meet in the centre* of the artery & *probably assist in the closure of the valves.*

CAUSE of the ACTION of the HEART.

The contractions of the heart are *not governed directly by the cerebro-spinal nerve-centres*, for injury to the latter amounting even to total destruction, does not, if gradually inflicted, stop the heart's action, and, if suddenly inflicted, generally occasions but a temporary interruption due to *shock*, especially if, in the case of warm-blooded animals, artificial respiration be resorted to. The action of the heart continues even after that organ has been completely disconnected from all other structures and removed from the body, and continues under such circumstances for several minutes in the case of warm-blooded, and for several hours in the case of cold-blooded animals.

The immediate cause of the heart's action lies, therefore, *within the heart itself, i.e., in the numerous ganglia & nerves of the sympathetic system*, which are distributed throughout the substance of the heart. (Vide "*Influence of the Nervous System over the Action of the Heart*.)"

THE SOUNDS of the HEART

Are *two* in number, follow *in quick succession,* and are *succeeded by a pause.*

1st. Sound.—Is *deep, dull, prolonged,* coincides with the impulse of the heart, & just precedes the pulse. Is best heard in the 5th intercostal space two inches below & one to the inner side of the nipple.

2nd. Sound.—Is *shorter, sharper, higher in tone,* and has a somewhat flapping character. It immediately follows the pulse, and is best heard at the upper border of the 3rd costal cartilage of the left side, close to the sternum.

The two sounds & the pause *correspond in point of time as follows :—*

1st. Sound—with:

A. The *contraction of the ventricles,* the closure of the auriculo-ventricular valves, the opening of the semilunar valves, & the projection of the blood into the arteries.

B. *The first part of the dilatation of the auricles.*

2nd. Sound—with:

A. The *cessation of the contraction of the ventricles,* the recoiling of the arteries, & the closure of the semilunar valves.

B. The *continued dilatation of the auricles,* the opening of the auriculo-ventricular valves, & the commencing dilatation of the ventricles.

The pause—with:

A. The *distention and subsequent contraction of the auricles.*

B. The *distention of the ventricles.*—During the pause the semilunar valves are closed and the auriculo-ventricular valves are open.

The two sounds *are determined as follows :—*

1st. Sound.—By several coincident causes, the principal of which is the *vibration of the auriculo-ventricular valves* at the moment of their closure, and also, perhaps, the vibration of the walls of the ventricles, aorta, and pulmonary artery. That such is the grand cause of the first sound of the heart is rendered more than probable, if it is not absolutely proved, by the following experiment of Valentin :—Valentin filled with a moderate quantity of water without any admixture of air a portion of a horse's intestine tied up at both ends; the stethoscope being applied to one of the ends, towards which end the water is propelled by sudden pressure at the other, a sound is heard very similar to the first sound of the heart; this sound is evidently produced by the vibration of the walls of the intestine. It is admitted, however, that other causes assist in producing the first sound; among these secondary causes the most efficient are probably the *contraction of the muscular fibres of the ventricles,* the *shock of the heart against the walls of the chest,* & the *vibration of the blood itself* when suddenly compressed and ejected into the arteries.

2nd. Sound.—By the *vibration of the semilunar valves* at the moment of their closure. This is proved by another of Valentin's experiments. Valentin passed curved needles through the walls of the arteries & the semilunar valves, thus rendering these immovable, and stopping their action; after the operation the second sound was no longer heard.

The *contraction of the auricles* is *inaudible through the walls of the chest,* but when the heart is exposed & the stethoscope is applied to it, a slight sound is heard preceding, & being continued into, the louder sound of the ventricular contraction.

Impulse of the Heart against the walls of the Chest

Is felt most distinctly *between the 5th & 6th left ribs, one or two inches from the sternum.*

It is *determined by* the *bulging out of the heart* during the ventricular contraction, & also by the *tilting forwards of its apex* in a screw-like manner, due to the spiral arrangement of the superficial fibres of the ventricles. The tendency of the aorta to straighten itself, when distended by the action of the ventricles is, perhaps, another cause of the impulse of the heart, but only a very secondary one, for the same tilting forwards occurs when the apex of the heart is cut off and the cavities of the ventricles are laid open.

STRUCTURE of the ARTERIES

Presents for examination *three coats*, the *vasa vasorum*, & *nerves.*

Inner, Serous or Epithelial Coat—Consists of *two essential structures* between which, in the large arteries, a third structure is interposed.—The two essential structures are :—

1. A *single layer of pavement epithelium*, the cells of which are slightly elongated, and present very distinct nuclei.

2. An *elastic* layer which may be either, as it usually is, a delicate *reticulated membrane perforated here & there, the striated or fenestrated coat of Henle*, or *a mere network* of anastomosing fibres of elastic tissue longitudinally disposed; or the two forms of elastic tissue may coexist, the former internally, the latter externally.—The intermediate structure observable in the large arteries is a longitudinal stratum (striated layer of Kölliker) of ill-developed elastic & connective tissue fibres, which stratum is often nearly homogeneous in appearance.

This coat is a *thin, brittle, colourless* membrane, remarkable for the *smoothness of its inner surface.* It can easily be separated from the middle coat by maceration.

Middle or Circular Coat—Consists of *alternate layers of circular muscular fibres* and of *circular fibres of yellow elastic & white fibrous tissues.* The relative proportion of these different elements varies according to the size of the vessel, the *muscular fibres* being most *abundant in* the *small arteries*, and forming almost exclusively the middle coat of the smallest ones, the *elastic & white fibrous tissues* being predominant *in* the *larger vessels*, and existing almost exclusively in the main trunks.

This coat is relatively *very thick*, and is the principal cause of the great thickness of the walls of the arteries. It is *elastic, but brittle*, of a yellowish or tawny colour in large arteries, redder in the smaller ones. It is easily separable from the outer coat.

External or Cellular Coat, or Tunica Adventitia—Consists of *connective tissue longitudinally or obliquely disposed*, and containing, except in the smallest arteries, elastic fibres and elongated nuclei. In the larger arteries the inner layers of this coat are formed of elastic tissue only, while the white fibrous tissue predominates in the outer layers.

This coat is proportionately thickest in the small arteries. It forms a tough investment, continuous externally with the sheath, by means of loose areolar tissue. It is in this coat that the vasa vasorum & nerves are principally seen to ramify.

Nutrient Arteries or Vasa Vasorum—Arise from the neighbouring branches, break up in the loose cellular tissue within the sheath, *ramify in the external coat*, and give off *a few twigs to the middle coat.* The corresponding venules open into the veins which accompany the artery.

Nerves—Are derived *principally from the sympathetic*, but, also from the cerebro-spinal system. They form plexuses on the large trunks; small bundles of fibres run along the smaller arteries, single fibres along the smallest. These penetrate into the middle coat, to which they are principally distributed.

ARTERIAL CIRCULATION.

The two properties by which the arteries influence the circulation are their *elasticity* & their *contractility.*

Elasticity of the Arteries.

The contents of the ventricles are forced into the arteries more rapidly than they can be discharged. The elasticity of the arteries therefore :—

1. *Prevents the arteries from bursting.*—The elasticity is most developed in the large arteries, especially in those near the heart, in which the variations of internal pressure are the greatest. The degeneration of the walls of the arteries is the principal cause of aneurism & apoplexy.
2. *Equalises the circulation* by maintaining pressure on the blood during the intervals of the ventricular contractions; the jetting stream is thus converted into the continuous and equable current observable in the capillaries.
3. Tends with the contractility to *maintain uniformity in the fulness & tension* of, and consequently in the rate of exudation from, and of absorption into, the vessels.

Contractility of the Arteries

Is most *developed in the small and in the middle-sized arteries.*—The contractility of the middle-sized arteries becomes evident to the naked eye when they are denuded and exposed to the air, or when they are cut through; in the latter case it tends to stay the hemorrhage, especially when cold or any irritating substance is applied. The contractility of the very small arteries is rendered still more evident by the microscopical examination of the mesentery of the frog & other small animals when either cold or heat, or mechanical, chemical, or electric stimuli are applied. It may last as long as 48 hours after death.

It is governed by the vaso-motor nerves, and is called into play by reflex action. It *regulates,* according to the requirements of the moment, the *quantity of blood that each part is to receive.* It co-operates with the elasticity in *adapting the calibre of the vessels to the total mass of the blood,* and in maintaining uniformity in the tension or tone of the blood-vessels.

Force of the Blood in the Arteries.

The onward force of the blood in the arteries has been measured by Poiseuille by means of the hæmadynamometer, and more recently by several experimenters by means of the kymographion.

It was *said* by Poiseuille *to be the same in all the arteries,* & to be capable of supporting, while the ventricles are contracting, a *column of mercury about six inches* or a *column of water about seven feet in height.* It is now, however, known to vary considerably in the different parts of the arterial system. It is increased by the injection of water or blood into the veins, and diminished by bleeding. It was said to be increased during expiration, and diminished during inspiration; the action of the respiratory movements appears, however, to be rather complex, the arterial pressure usually increasing, according to Dr. Burdon Sanderson, during inspiration and the commencement of expiration, and diminishing towards the end of the expiratory movement, & during the period of repose of the thorax.

The force with which the blood is propelled into the aorta by the *left ventricle* is calculated to be equal to *about* 4 *lbs.,* & the force with which it is propelled into the pulmonary artery by the *right ventricle* to be equal to *about 2 lbs.*

Velocity of the Blood in the Arteries.

Volkmann has shown with the hæmadrometer that the velocity of the blood is much greater in the arteries than in the capillaries, and also considerably greater than in the veins; that it is *greatest near the heart & during the ventricular contractions,* and *least during the ventricular diastole & in parts distant from the heart,* the two extremes being respectively *about* 10 & *about* 2 *inches per second.* The velocity of the blood is also slightly increased during expiration, and diminished during inspiration.

THE PULSE.

The jetting movement of the blood *dilates the arteries in all directions,* increasing both their *diameter* and their *length.* The lateral dilatation of the arteries is only about 1-15th (Vierordt) or 1-22ndth (Poiseuille) of their diameter. The *elongation* (which has not been accurately measured) *produces curvature or increases the natural curves, and causes a much greater displacement* of the arterial walls.

The pulse may be defined as *the beat of the arteries produced by their sudden dilatation and displacement, the latter due to the curvature produced by elongation, which dilatation & displacement are rapidly propagated in a wave-like manner* from the heart immediately after each ventricular contraction.

The nearer an artery is to the heart, the sooner after the ventricular contraction is the *pulse perceptible in it;* thus the pulse in the carotid precedes that in the radial, which in its turn precedes that in the dorsal artery of the foot. The delay of the pulsation in the distant arteries never exceeds, however, 1-6*th or* **1**-8*th of a second.*

The improved *sphygmograph* & the beautiful investigations of Mr. Marey have inaugurated a new period in the progress of our knowledge of the phenomena of the arterial circulation. The sphygmograph itself cannot be described here, nor can any but the most prominent results of the investigations of Mr. Marey and others:

1. The *distention of all the arteries begins at the same moment* & coincides with, or instantaneously follows, the contraction of the ventricles; it is *only the maximum* of dilatation and displacement which maximum alone is perceptible to the finger, *that is attained almost instantaneously in the proximate arteries, and slightly delayed in the distant ones.*

2. The *delay is thus accounted for:* the blood propelled by the ventricle into the aorta meets the blood already contained in that vessel, and is impeded by it in its course. This causes *a part of the force,* communicated to the blood by the ventricular contraction, to be *expended laterally in the dilatation of the first part of the aorta,* and *gives rise to the formation of a wave.* It is *this wave,* which, advancing at the rate of about 30 feet per second, *dilates in succession the different parts of the artery as it passes rapidly through them.*

3. The passage of each successive wave through an artery, or each pulsation, is marked in the pulse-tracing by an *upstroke;* a *downstroke* marks the intervals of the pulsations. The *upstroke ought not to be too vertical,* for deficiency of tone in the arteries is thus indicated. The *downstroke always presents a slight re-ascent,* which is probably due to the momentary rebound throughout the arterial system, occasioned by the closure of the aortic valves, which closure suddenly stops the incipient regurgitation of the blood into the ventricles. *When there is much loss of tone,* as in low fevers and after great loss of blood, this *re-ascent is exaggerated* and can be perceived by the finger; the *pulse is then* said to be *dicrotous.*

The frequency of the Pulse.

The pretty uniform *relative* average observed in health, between the number of the *beats of the heart* & the number of the *respirations,* is *about* **4** *or* **5** *to* **1.**

In round numbers the *average frequency of the pulse is:—*

Before birth	... ...	150 beats per minute.
At birth ...	... ...	140 „ „ „
1st year ...	... ...	120 „ „ „
7th year ...	... ...	90 „ „ „
14th year ...	... ...	80 „ „ „
Adult age ...	... ...	70 to 80 „ „ „
Old age ...	... ...	60 to 70 „ „ „
In decrepitude ...	... ...	65 to 75 „ „ „

THE STRUCTURE of VEINS

Differs more than that of the arteries according to size and situation. In *most veins three coats* can be recognised; they are, however, much thinner than those of the arteries.

Veins immediately above the Capillaries—Consist simply of a layer of *pavement epithelium,* supported on a stratum of *nucleated fibrous tissue,* longitudinally disposed, and generally divisible into two layers.

Middle-sized Veins—Present:

Inner Coat.—Formed from within outwards by a layer of *pavement epithelium,* one or more layers of *nucleated fibrous tissue* longitudinally disposed, and a longitudinal layer of reticulated *yellow elastic fibrous tissue.*

Middle Coat.—Formed of *alternating longitudinal & circular layers,* the former consisting of *white & reticulated yellow elastic fibrous tissues,* the latter of the same tissues with circular *muscular fibres.*—The muscular fibres are most developed in the splenic & portal veins.

Outer Coat.—Consists of *connective tissue* longitudinally or obliquely disposed.

Larger Veins—Have a *thick middle coat,* in which, however, the muscular tissue is but scanty.

Very Large Veins—Have a remarkably *thick outer coat,* which, especially in the large veins of the abdomen, contains a considerable number of *longitudinal muscular fibres* (Remak).—The venæ cavæ & pulmonary veins present near their termination a layer of striated muscular fibres continued upon them from the auricles.

Plain *muscular fibres* are *abundant* in the veins of the *gravid uterus.* They are, on the contrary, *wanting* in the veins of the maternal part of the placenta, in most of the cerebral veins, the sinuses of the dura mater, the veins of the cancellous tissue of bone, and in the venous spaces of the corpora cavernosa.

The *valves* of the veins are formed by a reduplication of the inner & middle coats.

The coats of the veins, as well as those of the arteries, are supplied with nutrient vessels, the *vasa vasorum.* Small nerves have also been traced on some of the larger veins of the abdomen.

VENOUS CIRCULATION

Is *equable*, slower than the arterial, but much quicker than the capillary.

Its *average velocity* is *about* 1-3*rd of* that of the *arterial in* the *corresponding peripheral veins*, the aggregate capacity of which is about three times that of the arteries. This velocity *increases*, however, as the blood advances *towards the heart*, in proportion as the aggregate capacity of the veins diminishes, and in the venæ cavæ it approximates that of the blood in the aorta. The motion of the blood in the veins is subjected, however, to many disturbing causes, such as the intermittent effects of muscular pressure, and the opposite influences of expiration & inspiration.

The pressure or *onward force* of the blood in the peripheral veins varies *from* 1-10*th to* 1-20*th* (Poiseuille), *or* is *about* 1-12*th* (Valentin) of that of the blood in the corresponding arteries. *Near the heart it diminishes* still more, and in the upper part of the vena cava scarcely any pressure can be detected; but then it must be remembered that the auricles dilate spontaneously, if indeed, they do not assist the flow of the blood towards the heart.

The *venous circulation* is *aided by* the action of the *valves* of the veins, and by the *respiratory movements.*

The Valves—Are found *in all* the *veins subject to pressure from the surrounding muscles*, and also in the *superficial veins*, and are most abundant in the extremities, particularly in the lower ones. They are *absent* in the *veins* of less than a line in diameter, in the veins *within the cranium, spinal canal, & abdomen*, in the pulmonary & umbilical veins, the veins of the cancellous tissue of bone. A few valves exist, however, in the spermatic veins, and one is found at their respective points of junction with the inferior vena cava & the left renal vein.

They are *semilunar* in form. Their free concave margin is directed towards the heart; they are attached by their convex margin to the wall of the vein, which is dilated immediately above them. They generally lie in pairs.

They are *formed by* a *reduplication of the two inner coats* of the veins, and consist of connective tissue and elastic fibres covered with a layer of pavement epithelium.

The design of the valves is twofold:

1. They divide the column of blood and *save the walls of the veins from the entire pressure of the whole column;* they are, therefore, on the latter account most needed in the unsupported superficial veins, where they are also most numerous. It is, however, inaccurate to say that they are intended to do away with the obstacle presented by gravitation to the venous circulation; this obstacle has no real existence, since the column of blood in the veins is supported by the equal weight of the column of blood in the arteries.

2. *In* the *deep veins* their action, combined with that of the surrounding muscles, is a *powerful assistant to the venous circulation.* When a vein is compressed by an adjoining muscle in a state of contraction, the first pair of valves in the direction of the capillaries closes immediately; the blood is then forcibly driven in the direction of the heart. It will easily be seen that it is the rapid succession of muscular contractions, and not their duration, that assists the venous circulation; were it not for the anastomoses of the veins the prolonged duration of the muscular contractions would even have a contrary effect.

The Respiratory Movements.

Inspiration.—It was *Sir D. Barry* who first showed the *aspiration or suction of the blood into the thorax during inspiration*, by the experiment of a bent glass tube introduced at one extremity into the jugular vein of a horse, & immersed at the other extremity in some coloured fluid: the fluid was drawn up into the tube during each inspiration. It is, however, *only in the veins of the base of the neck*, the walls of which are more or less attached to bones and are supported by the deep cervical fascia, *that* the influence of inspiration *extends to any distance out of the thorax;* the opening of any such veins often gives rise to the now well-known phenomenon of the aspiration of air into the circulatory system.

Expiration.—*Favours the arterial circulation* by increasing the pressure in the arteries; its *effect on the venous circulation* must be the *reverse.* The action of the *valves prevents*, however, any *rapid expiratory movement from* seriously *impeding* the *circulation;* prolonged expirations rapidly produce congestion of the head & neck.

THE CAPILLARIES

Form a *microscopical network*, which is everywhere interposed between the arteries & the veins, except between some of the arteries and veins of the erectile structures and of the spleen & maternal part of the placenta.

This network is much more *uniform in the size & shape of its meshes* than that which is formed by the anastomoses between the small arteries & the veins; the vessels which form it maintain the same diameter throughout. In *form* it presents *three principal varieties*; the meshes being either *rounded*, as they commonly are, or *elongated*, as they are in the muscles and nerves, or arranged *in loops*, as they are in the papillæ of the tongue & skin.

The more active the functions of an organ or tissue are *the more numerous* are its *capillaries*. In the *lungs*, the *liver*, & the *choroid coat* of the eye, in which the capillary network is closer than in any other structure, the interspaces between the capillaries are smaller than the capillaries themselves; *ligaments*, *tendons* and allied structures are but slightly vascular.

The *usual diameter* of the capillaries is *about* 1-3000*th* of an inch. Among the *largest* capillaries rank those of the *skin*, and those of the *marrow* of the bones, which are sometimes 1-1200th of an inch in diameter; among the *smallest* are those of the *brain* & of the *mucous membrane of the small intestine*, the diameter of which sometimes does not exceed 1-4500th. The so-called *serous vessels*, which were described in the cornea, and which were said to be too small to transmit the red globules of the blood, are now not generally believed to exist.

The *walls* of the capillaries have until lately been believed to consist simply of a *transparent structureless membrane*, formed of a single layer of flattened nucleated cells, *which are* so perfectly joined together that their nuclei alone can be distinguished like so many *minute oval corpuscles*, imbedded at intervals in the otherwise homogeneous wall. *Externally to this* membrane there is *now believed* to exist *another homogeneous structure*, on the inner surface of which the epithelial scales are laid down.

Two varieties of large capillaries, or *vessels of transition* between the ordinary capillaries and the arteries & veins, are described by some authors. On the smaller of the two a thin layer of circular muscular fibres can be seen; on the larger variety an additional covering of connective tissue begins to appear.

CAPILLARY CIRCULATION

Can *easily* be *observed* with the microscope *in all thin, transparent parts,* such as the web of a frog's foot, the tail and gills of tadpoles or small fishes, or the mesentery of small quadrupeds.

Is *remarkably slow;* and it is *uniform,* at least in the strong and healthy adult.

Its *velocity* is *greatest in the centre* of the stream, which is occupied by the red globules. *At the sides* is a *"still layer" of liquor sanguinis,* apparently motionless, in which lymph corpuscles may sometimes be seen moving slowly along, or even adhering to the walls of the vessel.

In *very young animals,* and also in adults when much blood has been lost, or when the heart's action is weak, the motion of the blood in the capillaries, on account of the incomplete distension and imperfect elastic recoil of the arterial walls, becomes *pulsatory,* and *even intermittent* when the degree of exhaustion is very great. The red globules are even seen occasionally to recede a little during the intervals of the arterial pulsations.

The rate of the capillary circulation in the *frog* is about 1 *inch per minute, or* 1-60*th of an inch per second, in the systemic capillaries,* and about *five times as great in the pulmonic capillaries.* It is estimated that the velocity of the capillary circulation *in man and in warm-blooded animals* is about *two or three times as great.*

The slow course of the blood in its passage through the capillaries is confined to a very short space, for the *whole length of the capillary vessels through which in any one part of the body the blood has to pass* before reaching the veins, *does not exceed* 1-30*th of an inch;* the *time during which the blood is detained in the capillaries* does *not* therefore *exceed one second.*

The *slowness* of the capillary circulation is *due to* the *widening of the stream* of blood in the capillaries, the aggregate sectional area of which is much greater than that of the arteries or veins, and also to the greatly *increased resistance arising from friction.*

When *cold or any irritating substance* is applied to a part, the capillaries are seen to *diminish in size.* They, however, properly speaking, cannot be considered to contract. It is the arteries alone that contract; less blood then passing through the capillaries, the elasticity of the latter causes them momentarily to shrink. The capillaries do not, therefore, appear to exert any direct mechanical influence over the movement of the blood. It is probable that it is some increased tendency of the globules to adhere to each other & to the walls of the capillaries that causes the partial or total arrest of the circulation in inflamed parts, & also in the lungs during asphyxia.

It is in the capillaries that the blood comes in closest contact with the tissues, and that those interchanges principally take place which ensue in the processes of nutrition & secretion.

ALLANTOID or PLACENTAL FŒTAL CIRCULATION.

The arterial blood returns from the placenta through the *umbilical vein*, which vein in the longitudinal fissure of the liver :—

A, gives off *a few small branches to* the lobus quadratus & the lobus Spigelii of the *liver*, and a few small branches and one large one to the left lobe (which latter large branch becomes after birth the left branch of the vena portæ);

B, *divides into two* terminal *branches*, of which

One, the larger, *joins* the upper part of the fœtal *portal vein* (which upper part subsequently becomes the right branch of the portal vein of the adult)—while

The other, the smaller, termed the ductus venosus, *joins* the *left hepatic vein* at the point of junction of the latter with the inferior vena cava.

All the blood from the umbilical vein passes therefore *into the inferior vena cava, either directly or indirectly.*

The blood passes from the inferior vena cava into the *right auricle* and is guided from thence by the Eustachian valve and the foramen ovale into the *left auricle*, from which latter cavity it descends into the *left ventricle.*

It is propelled by the left ventricle into the *arch of the aorta*, from whence it ascends almost entirely to the *head, neck, and upper extremities*, a very small quantity passing down the descending aorta to the remainder of the body.

From the head, neck, and upper extremities the blood *returns by the superior vena cava to the right auricle.*

This time it passes into the *right ventricle.*

From the right ventricle it is propelled into the *pulmonary artery.*—Very little blood goes to the lungs, which are almost impervious; nearly all passes through the *ductus arteriosus* into the *descending aorta*, by which it is conveyed to the *trunk and lower extremities, a part returning to* the *placenta by* the *hypogastric arteries, and their continuation, the umbilical.*

In this course the arterial blood is several times admixed with venous blood, no part of the body, except a small portion of the liver receiving absolutely pure arterial blood; thus :—

On entering the liver the principal current of arterial blood is mixed with the blood of the portal vein;

On entering the inferior vena cava the mass of the arterial blood is mixed with the blood returning from the lower extremities;

When traversing for the first time the right auricle, the arterial blood probably bears away with it a part of the blood returning to the heart by the superior vena cava.

It is this "*arterial*" *blood, three times admixed with venous blood*, relatively pure, however, that passes up *to the head, neck, and upper extremities*, hence the relatively greater development of these parts.—It is *only after* this blood has *circulated through the head, neck, and upper extremities that* it is returned to the heart, and is thence *directed, after having received but two slight additions of purer blood* in the right auricle and from the arch of the aorta, *towards* the *trunk and lower extremities*; hence the lesser development of the latter.

At birth an *increased amount of blood passes* from the pulmonary artery *to the lungs*; as this blood *returns aerated* to the left auricle by the pulmonary veins, an *increased supply of pure blood is received by the left side of the heart*; the *closure of the foramen ovale* soon *stops the arrival of the mixed blood*, which previously distended that cavity.—The *pure arterial blood* is soon propelled *equally into* the arteries of the *head, neck, and upper extremities and into the descending aorta*, for the closure of the ductus arteriosus stops the arrival into the latter vessel of the current of mixed blood from the right side of the heart, which current had hitherto impeded the descent towards the lower extremities of the blood propelled by the left ventricle. All the parts of the body then receive equally pure blood.—The placental circulation ceasing, *the umbilical arteries & veins and the ductus venosus* become obliterated and *transformed into fibrous cords*, the arteries remaining pervious, however, under the name of *superior vesical*, as far as the bladder, the upper part of which they supply.

APPENDIX

TO

CIRCULATION.

I.—ACTION OF THE HEART.

II.—SCHEMATIC CIRCULATION.

III.—SECONDARY WAVES.

IV.—EFFECTS OF VASO-MOTOR ACTION, AND LOCAL VASO-MOTOR MECHANISMS.

V.—COAGULATION OF THE BLOOD.

(See also pages 12ᴱ and 24 & 25ᴬ in Appendix to Respiration.)

ACTION of the HEART.

Visible Movements:

(Chest opened, Heart exposed, Artificial Respiration kept up.)

A peristaltic wave runs along the great veins (superior & inferior cavæ, & pulmonary) towards the auricles, increasing in intensity as it progresses.

This wave then spreads rapidly over the auricles: The walls of these cavities are pressed towards the auriculo-ventricular openings; the appendices are drawn inwards, and become smaller & paler. The ventricles become turgid.

As the wave reaches the ventricles, these become harder, more rounded, & shorter. Their base moves downwards towards the apex of the heart, and, as a consequence, the aorta & pulmonary artery elongate. The apex of the heart moves forwards & to the right, exposing more of the left ventricle.

During the diastole the ventricles flatten & elongate; their base is drawn upwards by the shortening of the aorta & pulmonary artery; the heart turns backwards & to the left.

The three Pins inserted into the Heart.

If three pins, inserted through the chest-wall into the apex, middle, & base of the ventricles, are carefully watched during the beats of the heart, the heads of these pins will be seen respectively, that of the first one merely to quiver, that of the second one to incline slightly upwards, that of the third one to incline upwards a good deal more. Further, the nearer the middle pin is to the lower one, the less it moves; the nearer it is to the upper one, the more it moves. – This shows that the apex of the heart does not move in the vertical direction, and that the other parts move downwards towards the apex in proportion to their distance from it. After death the heads of all the three pins are inclined downwards, showing that the heart, as a whole, has been drawn upwards by the shortening of the aorta & pulmonary artery.

ACTION of the HEART (continued).

Registration of the Beats, and of the Variations of Intra-Auricular & Intra-Ventricular Pressure.

(CARDIOGRAPH APPLIED TO CHEST-WALL, SMALL ELASTIC BAGS COMMUNICATING WITH SEPARATE TAMBOURS INTRODUCED THROUGH INTERNAL JUGULAR VEIN INTO RIGHT AURICLE & RIGHT VENTRICLE OF A HORSE; ORDINARY RECORDING APPARATUS.—Marey).

Counting the cycle from just after end of ventricular systole, we find:

1. – *Steady rise of auricular, ventricular, & cardiographic curves for about $\frac{4}{10}$ of a second:* – The blood, poured from the great veins into the auricles, increases the pressure in these cavities; poured from the auricles into the ventricles, it increases the pressure in the latter; the distended ventricles press against the chest-wall.

2. – *Sharp rise and fall of auricular curve occupying together about $\frac{3}{10}$ of a second; slight corresponding rise & fall of ventricular & cardiographic curves:* – Contraction & relaxation of auricles, distension of ventricles, slightly increased pressure of the latter against chest-wall.

3. – *Great & sudden rise of ventricular curve lasting, with but a slight decline and a few undulations, for about $3\frac{1}{2}$-10ths of a second; corresponding rise & undulations of cardiographic curve; slight undulations of auricular curve:* – Ventricular systole; beat of heart against side of chest. – The intra-ventricular pressure rapidly reaches its maximum, which is all but completely maintained during the time specified. The undulations are probably due to vibration of the auriculo-ventricular valves.

4. – *Great & sudden fall of ventricular curve, and corresponding fall of cardiographic curve, lasting about $2\frac{1}{2}$ 10-ths of a second:* – Ventricular diastole; end of the beat. – Both curves, and also the auricular curve, present here a slight transitory rise probably due to the vibration of the semilunar valves.

The cardiac cycle lasts therefore about $\frac{12}{10}$ of a second. Nearly half this time is occupied by the systole, first of the auricle, then of the ventricle; a little more than half is occupied by the 'passive interval,' or period of repose of the heart.

The Work done by the Heart.

During their systole, the pressure in the right and left ventricles is respectively about 30 or 40, and about 200 mm. of mercury, the total pressure corresponding to that of about 3 metres of blood. Taking the quantity of blood ejected by each ventricle during its systole at about 180 grms., or 6 ounces, this gives a total of more than 600 grammetres of work for each beat, or about 60 or 70 thousand kilogrammetres per day. Taking, further, the total quantity of blood in the body at $\frac{1}{13}$ of the body weight, it is clear that the whole of the blood, or a quantity equivalent to the whole of the blood, must pass through the heart in between 30 & 40 beats, or in about $\frac{1}{2}$ a minute. – The pressure in the right auricle during its systole is about 2 or 3 mm. of mercury; this pressure is said to become negative immediately after the systole. The pressure in the left auricle has not been ascertained.

SCHEMATIC CIRCULATION.

Attempts at an artificial imitation of the circulation of the blood throw considerable light on the circulatory mechanism:

Let us consider the action of a force-pump combined with

I. – *A System of Rigid Tubes.* – During each stroke of the pump there escapes from the distal end of the system just as much fluid as enters at the proximal end. In every part the flow is intermittent and synchronous with the action of the pump. It matters not whether a resistance be introduced, in imitation of that opposed by the small arteries & capillaries to the movement of the blood. Such resistance would diminish the quantity of fluid issuing at the distal end simply by diminishing the quantity entering at the proximal end; it would not modify the intermittent charater of the circulation.

II. – *A System of Elastic Tubes without a Resistance.* – Such a system is practically the same as the foregoing. The outgo being easy, the elasticity of the tubes is not called into play; the flow is still intermittent & synchronous with the strokes.

III. – *A System of Elastic Tubes with a Resistance Interposed.* – On the one hand, the fluid, being unable to pass the resistance as rapidly as it enters from the pump, tends to accumulate on the proximal side of the resistance. On the other hand, the distended tubes, reacting upon the accumulated fluid, tend to force it through the resistance during the intervals of the strokes. The flow tends, therefore, to become continuous. And if the resistance, the force of the pump, and the elasticity of the tubes are all sufficiently great, the flow will practically become, not only continuous, but equable. For then the greater part of the force of the pump would be spent in getting up, and afterwards in keeping up, the over distension of the tubes, and it would be left mainly to the elastic recoil of the tubes to keep up the flow.

This is not a bad simile of the vascular mechanism: – The elastic and distended arteries are continually striving to drive the surplus blood they contain through the capillaries into the veins; and the heart is continually overfilling the arteries, and keeping them distended.

Should the arterial walls lose their elasticity, or should the arteries cease to be distended, either through insufficient action of the heart, or through greatly diminished resistance on the part of the capillaries, the venous circulation would immediately become more or less pulsatory, or even intermittent.

SECONDARY WAVES.

Secondary Schematic Waves.

Two kinds of secondary waves may be developed in the schema, *waves of oscillation* & *reflected waves.*

The *waves of oscillation* are due to the inertia of the fluid & of the elastic tubes. Therefore the denser the fluid, the more extensible & elastic the tubing, the more sudden the stroke, and the less the pressure, the more marked they are: if mercury be used, they are very conspicuous; if the tubes be filled with air, they are almost absent. They form a regular decreasing series succeeding the primary wave and traveling in the same direction & at the same rate.

Reflected waves occur when the circulation is arrested in any part of the schema by the blocking of the tube. These waves travel at the same rate as the primary or direct waves, but in the opposite direction, *i. e.*, backwards towards the pump.

At the block each reflected wave blends with the corresponding primary or direct wave. At any point of the tube between the pump & the block, each reflected wave follows the *corresponding direct* wave at an interval of time proportionate to the distance between such point & the block.

If the relation be considered between a reflected wave and the *next ensuing* direct wave, it will be seen that, in its retrograde course, the former meets, blends with, and then separates from the latter at a point in the schema, the situation of which point will depend jointly upon the length of tube between the pump & the block, and upon the length or rate of succession of the direct waves.

If, therefore, the recording lever be successively shifted from one point to another, or if several levers be applied to different points of the tube, it will be found (1) that the interval between the reflected wave and *corresponding or preceding* primary wave decreases with the diminishing distance between the point observed & the block, and (2) that the interval between the reflected wave and the *next ensuing* direct one first decreases with the diminishing distance between the point observed & the pump till it becomes nil, and then again increases with such latter diminishing distance.

The secondary schematic waves throw considerable light on the

Secondary Pulse-waves.

Two are usually recognised, the *predicrotic* or *tidal*, & the *dicrotic*; the latter, which occurs towards the end of the descent, being the most marked of the two.

There is in fact some uncertainty with regard to the former. In some cases it would appear to be due to the vibration of the spring of the sphygmograph, for it is sometimes wanting when no spring is used, and when the spring used has a short vibration-period, it may be broken up into a series of two or more undulations. When clearly physiological, it appears to coincide with the first of the series of undulations of the ventricular curve which follow the sudden rise due to the ventricular systole.

The *dicrotic* wave is sometimes so marked as to give rise to the appearance of a double pulse; sometimes both it and the tidal wave are scarcely perceptible. It is most pointed in the aorta & in the large arteries near the heart.

Neither of these waves is a reflected wave, for the interval between either & the primary wave is found to be the same in whatever artery the pulse be recorded. Hence these waves travel in the same direction as the primary wave, *i. e.*, towards the periphery, and at the same rate. They are, therefore, waves of oscillation.

But, if they are waves of oscillation, how is it that the second one (the dicrotic) is more marked than the first (the tidal or predicotic)? Some event must intervene to exaggerate this particular wave. This event is probably the sudden closure of the semilunar valves.

The occurrence of the secondary pulse-waves is favoured by the same conditions which, in the schema, favour the production of waves of oscillation, *i. e.*, sharp ventricular systole, low pressure, perfect elasticity and extensibility of the arteries: Dicrotism may be induced by diminishing the peripheral resistance through section of the splanchnic nerves; it is not seen in arteries rendered rigid by disease.

EFFECTS of VASO-MOTOR ACTION.—General View.

EFFECTS of ARTERIAL DILATATION.

Are first Local:-

THE DIMINUTION OF PRESSURE IN PASSING FROM THE ARTERIES INTO THE VEINS IS LESS MARKED THAN USUAL. Hence

The Pressure in the Veins is increased, and

The Pressure in the Arteries is diminished. – The pressure in the arteries being diminished, the arterial walls are less distended, their elasticity is called into play to a less extent, and to a less extent also is the intermittent current equalised: The circulation in the veins is therefore pulsatory.

MORE BLOOD IS ACCUMULATED IN THE AFFECTED AREA, AND THE FLOW OF BLOOD THROUGH IT IS ACCELERATED. Hence

The Sum Total of the Molecular changes is increased, and the Temperature is raised. Nevertheless

The Blood is less completely Dearterialised, and, in the veins, it has still the arterial hue.

Then General:-

THE GENERAL ARTERIAL PRESSURE IS LOWERED, through diminished peripheral resistance in the affected area.

THE TOTAL QUANTITY OF BLOOD IN THE OTHER AREAS IS DIMINISHED, through more blood being accumulated in the area affected.

EFFECTS of ARTERIAL CONTRACTION.

Are first Local:-

THE DIMINUTION OF PRESSURE IN PASSING FROM THE ARTERIES INTO THE VEINS IS MORE MARKED THAN USUAL. Hence

The Pressure in the Arteries is increased, and the pressure in the Veins is diminished.

LESS BLOOD IS CONTAINED IN THE AFFECTED AREA, AND THE FLOW OF BLOOD THROUGH IT IS RETARDED. Hence

The sum total of Molecular changes is diminished and the Temperature is lowered. Notwithstanding that,

The Blood is more completely dearterialised than usual.

Then General:-

THE GENERAL ARTERIAL PRESSURE IS INCREASED, through increased peripheral resistance in the affected area, and

THE TOTAL QUANTITY OF BLOOD IN THE OTHER AREAS IS ALSO INCREASED.

EFFECTS of VASO-MOTOR ACTION.—Special View.

Only the general, or only the local, effects may be conspicuous; or both may be well marked, one in one direction, the other in the other direction:—In a rabbit under the influence of urari, irritation of the central end of the divided great auricular nerve induces both a general rise of the arterial pressure, and the dilatation of the arteries of the ear.

LOCAL VASO-MOTOR MECHANISMS.

Local vaso-motor mechanisms capable, not only of maintaining, but, within certain limits, of regulating local arterial tone, are inferred from the following facts:—

In the apparent absence of all disturbing causes, certain small arteries are seen to vary greatly in size, these variations assuming sometimes an almost rhythmical character. This is the case with the principal artery of the ear of the rabbit. If the sympathetic be divided, these variations will cease for a few days, but will then recommence and continue as before.

The increased vascularity induced by the division of vaso-motor nerves, disappears almost entirely after a short time, leaving the parts apparently in their normal condition, and still capable of increased or diminished vascularity under irritation.

The circulation of the submaxillary gland seems to be influenced by a centre of its own (See Appendix, page 40B).

The normal condition of the erectile organs appears to be independent of the integrity both of the spinal cord & of the *nervi erigentes* (See pages 89 & 100).

As to the nature of such local mechanisms, if they exist, we are entirely in the dark: no ganglia have been found either in the rabbit's ear, or in the web of the frog's foot, where similar vascular variations may be observed.

The subject of the *constrictor & dilator nerves* is discussed pages 109 & 110.
See also Appendix page 12E (after page 20A).

COAGULATION of the BLOOD.

Is caused by its becoming pervaded by a meshwork of fine granular fibres of fibrin due to the interaction of three factors, – *fibrinoplastin, fibrinogen, & fibrin-ferment;* – the latter factor resulting from the death of the white blood corpuscles, and being set free by their disintegration.

THE THREE FIBRIN-FACTORS.

FIBRINOPLASTIN & FIBRINOGEN. – PLASMINE.

Fibrinoplastin & fibrinogen are globulins (V. Animal Chemistry) found in many parts of the body, and so similar to each other that they can scarcely be distinguished. They are both insoluble in distilled water, and in saturated neutral saline solutions, (sodium chloride, magnesium sulphate, etc.), but soluble in *dilute* neutral saline solutions. They are prepared through precipitation from their solutions by one or other of the following methods, namely, by saturating these solutions with sodium chloride, or by diluting these solutions with from ten to twenty times their bulk of water and then driving through them a brisk current of carbonic acid gas: The precipitate of fibrinoplastin is first flocculent, then granular; the precipitate of fibrinogen is viscous & adherent to the bottom of the containing vessel, and it takes a longer time to appear.

Fibrinoplastin is usually obtained from blood-serum; but it may also be obtained from connective tissue, the cornea, etc. Fibrinogen is usually obtained from serous transudations, such as the pleural, pericardial, & peritoneal fluids, & the fluid of hydrocele.

A clot is formed when solutions of these two bodies are mixed together, or when fibrinogen is added to serum, or fibrinoplastin to hydrocele fluid. On the other hand, serum deprived of its fibrinoplastin, and hydrocele fluid deprived of its fibrinogen, have lost all coagulating power.

Fibrinoplastin & fibrinogen can be obtained *together* from any fluid containing them both, *e.g.* uncoagulated blood-plasma*. On saturation with sodium chloride, uncoagulated blood plasma yields a white, flaky, and somewhat sticky precipitate termed *plasmine* (Denis). This is a mixture of fibrinoplastin & fibrinogen. It is soluble in a dilute sodium chloride solution, or, in fact, as above prepared, in distilled water, since a certain amount of sodium chloride then remains adherent to it. The solution is at first perfectly fluid, but it soon becomes viscid, and then clots like blood plasma.

FIBRIN-FERMENT. – V. Next Tablet.

**E.g.*, the plasma either of horse's blood, which may be kept from coagulating by simply lowering the temperature to about 0° C., or of any other blood, which may be kept from coagulating by its being mixed with one third of its bulk of a saturated solution of some neutral salt, such as magnesium sulphate.

FIBRIN-FERMENT.

This, like the digestive ferments, is a non-nitrogenous substance, which acts catalytically on the two other fibrin-factors, *i.e.*, promotes their union and the consequent formation of fibrin, without entering into the composition of the fibrin produced. On being added to uncoagulated blood-plasma, or to any fluid containing both fibrinoplastin & fibrinogen, it gives rise to a *rapid* coagulation, while a *relatively slow* coagulation would otherwise have taken place; but this addition in no wise affects the *quantity of fibrin* produced. Neither does any coagulation result from fibrin-ferment being added to a fluid containing either fibrinoplastin or fibrinogen *alone*.

This fibrin-ferment results from the death of the white corpuscles, and is set free by their disintegration. Some of the facts proving this are easily observed with the microscope in the case of the blood of the horse, which blood coagulates but slowly if a low temperature be maintained: – No coagulation takes place till some of the corpuscles begin to break up; and then the first threads of fibrin are seen to radiate from these broken up corpuscles, as from centres.

The fibrin-ferment can easily be obtained by the alcohol & water and alcohol & glycerine methods employed for the preparation of the digestive ferments (V. Appendix, page 36A), and the circumstances connected with the preparation supply further facts in support of the foregoing statements: – If blood-serum or defibrinated blood be received into about twenty times its bulk of alcohol, and the coagulum be first left to stand under alcohol for some time, and then be dried and extracted with water or glycerine, the extract, though containing little or no proteid material, will be found to hold fibrin-ferment in solution. The solution will be a weak one if the blood-serum or defibrinated blood is operated on soon after the blood is poured out from the vessels; it will be much more active if the operation is delayed for a time, especially if it is delayed till coagulation sets in. Further, if horse's blood be used, and if, by cold or otherwise, * it be kept from coagulating till the red corpuscles have sunk to the bottom and the white ones have floated to the top, it will be found that fibrin-ferment can be obtained in abundance from the upper strata of the fluid, in small quantities only from the lower ones. And again, if a portion of the upper strata of the fluid be filtered and thus freed from white corpuscles, little or no fibrin-ferment can be obtained from them; from the residue, on the contrary, *i.e.*, from the white corpuscles themselves, a large amount of ferment can be extracted. All fluids spontaneously coagulable are rich in white corpuscles; and the more abundant these are, the more pronounced is the coagulation.

* *E.g.*, by dilution with a saturated solution of some neutral salt, such as magnesium sulphate, as already explained.

HOW BEST TO OBSERVE THE PROCESS.

The process of blood-coagulation can be retarded, and can then be more easily watched, by the blood being diluted with a considerable proportion of a weak sodium chloride solution, – say with fifty times its bulk of a ·75 per cent. solution. Fine fibrils of fibrin will then be seen to spring from the sides & bottom of the vessel, and, little by little, to extend throughout the mass, which will now become first viscid, and then more opaque & jelly-like. If picked up on a needle or glass rod, the fibrils will shrink into a small stringy mass, which will float in the fluid; and, if the fluid is stirred from time to time, all the fibrin can be removed piecemeal, and coagulation entirely prevented. When fresh blood is whipped with a bundle of rods, the rods become covered with a mass of shrunken fibrin, and no coagulation occurs.

NOTES.

It would appear that the fibrinogen is a normal constituent of the blood-plasma; but that the white corpuscles are the source, not only of the fibrin-ferment, but also of the fibrinoplastin: – Filtered blood plasma coagulates, not only slowly, on account of the small amount of fibrin-ferment present, but also feebly. This is due to the small amount of fibrinoplastin it contains; for if fibrinoplastin be added, the clot formed will be as abundant & firm as that which can be obtained from the same amount of *unfiltered* plasma.

Those corpuscles, which are clearly seen, in the blood of the horse, to be intermediate in character between the red corpuscles & the white ones, *i.e.*, to be nucleated cells whose protoplasm is loaded with hæmoglobin granules, are also believed to be a source both of the fibrinoplastin & of the fibrin-ferment (Schmidt). In the lower vertebrates, the nucleated red corpuscles, which are clearly the homologues of the above-mentioned intermediate forms, appear even to give off, not only fibrinoplastin & fibrin-ferment, but also fibrinogen.

Fibrinoplastin prepared by the saturation method always contains a certain amount of fibrin-ferment: – The addition of fibrinoplastin so prepared, either to uncoagulated blood-plasma, or to pericardiac fluid, greatly accelerates coagulation. The fibrin-ferment appears to be absent from fibrinoplastin prepared by the carbonic acid method.

The fibrinoplastin & the fibrinogen do not appear to unite in precise & definite proportions, as do an acid & a base: in whatever proportions they are brought together, the quantity of fibrin formed is always less than that of the fibrinoplastin present.

The conception of the coagulation of blood as a chemical process, though, from the above fact, it does not appear well founded, has nevertheless the advantage of giving an easy explanation of the accelerating influence of such conditions as heat, motion, contact either with rough surfaces, or with porous or pulverulent bodies, etc. The influence of other conditions is, however, obscure: there is nothing which explains the retarding action of alkaline & sedative salts, of narcotic & sedative alkalis, etc., nor why a certain amount of some neutral salt, such as sodium chloride, must of necessity be present.

COAGULATION in the BLOOD-VESSELS.

DURING LIFE.

Causes which induce it.

These are the presence of foreign bodies and the occurence of injured or diseased spots in the vascular parietes. Such conditions attract, and then doubtless cause the death & disintegration of, a certain number of white blood-corpuscles; hence the production & effusion of the fibrin-ferment, which leads to the coagulation: – For a ligature on an artery to cause coagulation, it must rupture the inner coat; and if this be done, coagulation will take place whether the ligature be left *in situ* or not.

Causes which prevent it.

We are driven to the conclusion that the parietes of the living vessel destroy the fibrin-ferment; and it is asserted on the strength of experimental results that this is the case: – As a rule, no coagulation is caused by injecting into the vessels of a living animal either fibrin-ferment, or defibrinated blood; and, on the other hand, the ferment, which can be detected in the blood immediately after the injection, rapidly disappears. Other tissues, that of the pericardium, for example, also appear to have the same power of destroying fibrin-ferment, even after death: healthy pericardial fluid removed from the body immediately after death generally coagulates rapidly; if it be removed some hours after death, it does not coagulate, or coagulates but slowly & feebly.

AFTER DEATH.

Causes which induce it,

Appear to be essentially the same as those which induce coagulation during life, *i.e.*, the death & disintegration of white blood-corpuscles: – After death, the blood in the vessels does not coagulate till post-mortem changes set in; and it will further be shown below that, when coagulation does set in, it commences where white corpuscles have previously accumulated.

Causes which prevent it.

Also appear to be essentially the same as those which prevent coagulation during life, *i.e.*, such as may be believed to cause destruction of the fibrin-ferment; at least the facts drive us to this conclusion. And, in this sense, are we compelled to admit a vital power exercised by the blood vessels, *i.e.*, a certain normal relation or equilibrium existing between them & the blood, which, as long as it is maintained, keeps the latter from coagulating. When this power wanes, when this equilibrium becomes disturbed, then does the blood begin to coagulate – *first in the larger vessels, then in the smaller ones.** After being tied at both ends, a large vein may be excised, without the contained blood coagulating for twenty-four hours or more; the same with the blood in an excised frog's heart, and with the fluid in an excised pericardium: neither will coagulate for several hours. The vein may be opened at its upper part, and thus transformed into a kind of test-tube open to the air, without coagulation occuring; and if two such test-tubes be prepared at the same time, the blood may further be poured out of one tube into the other, also without coagulation occuring. When removed from the vessels, however, the blood coagulates at once.

Anything which causes an accumulation of white blood corpuscles, and thus overstrains, as we may suppose, the power of the vessels to destroy the nascent ferment, soon causes coagulation: – The corpuscles cluster round any foreign body, such as a thread, needle, or piece of wire; and from the nucleus thus formed a clot is soon seen to radiate in all directions. The tapering coagulum passing up, in a ligatured artery, from the ligature as far as the nearest collateral, is formed in obedience to this law.

* *I.e.*, first in those vessels, where a relatively large amount of blood is but imperfectly restrained from coagulating by a relatively small amount of surface; then in those vessels, where a relatively large amount of surface more efficiently restrains the coagulation of a relatively small amount of blood.

RESPIRATION.

MECHANISM of RESPIRATION.

The air is alternately drawn into, and expelled from, the lungs by the two successive movements of *inspiration & expiration*, which movements are *followed by a pause* or period of repose of the thorax.

Inspiration—Consists in the *dilatation of the thorax by muscular action*, and in the *consequent distention or inflation of the lungs*, by the air rushing in through the windpipe to fill up the threatened vacuum.

In inspiration, the *thorax* is *enlarged in each of its three diameters* :—

The *enlargement in the vertical direction* is always the *greatest*, especially in the young, and is due to the descent of the *diaphragm* during its contraction.

The enlargement in the two *horizontal diameters*, viz., the antero-posterior and the transverse, is *most marked at the lower part of the thorax* in the *male*, and at the *upper part* in the *female*, the difference constituting the two grand types of respiration, the *abdominal or inferior costal* and the *superior costal or pectoral*. It is *due* to the *elevation of the ribs and* consequent *elevation & projection forwards of the sternum*, and also to the *rotation of the ribs upwards round an axis passing through their anterior and posterior extremities* somewhat after the fashion in which the handle of a bucket is raised.

The principal inspiratory muscle is therefore the *diaphragm*.

The *auxiliary inspiratory muscles* are the muscles that raise the ribs.—They may be divided into *three groups*, which are respectively called into play: in ordinary tranquil breathing, in deep inspirations only, and in extreme emergencies only. These groups are:

1. The *external intercostals*, with perhaps the part of the internal intercostals, comprised between the cartilages of the ribs, and the levatores costarum. It was supposed at one time that the external intercostals could not raise the ribs unless the uppermost rib were first fixed by the scaleni (and also that the internal intercostals could not depress the ribs unless the lower ones were maintained by the abdominal muscles), but this has been shown to be inaccurate both theoretically and by observations on living animals.

2. The *anterior & posterior scaleni*, the cervicalis ascendentes, the posterior superior serrati; and also the *pectorales major & minor, serratus magnus*, latissimus dorsi, & *subclavius*, when the scapula & clavicle, and consequently the humerus, are fixed by the trapezius, sterno-mastoid, levator anguli scapulæ, & rhomboidei.

3. *Nearly all the muscles of the body* may assist *in violent inspiratory efforts* by removing from the thorax, and fixing at a distance, the points of origin of the foregoing muscles, and thus rendering their action more efficient: the head is thrown back and the arms are frequently uplifted in fits of dyspnœa.

Expiration—Consists in the *elastic recoil of the whole respiratory apparatus*, which recoil may be *aided*, either to a slight or to a considerable extent, *by the compression of the thorax by muscular action.*

The *ordinary expiratory muscles* are the *internal intercostals* (with the exception, perhaps, of their fore part comprised between the costal cartilages), to which may be added the infracostales, the triangularis sterni.

The *auxiliary muscles of expiration*, which are called into play in voluntary expiratory efforts, as in speaking, singing, blowing, etc., or in dyspnœa, are all the other muscles that depress the ribs, such as the *abdominal muscles*, external & internal oblique, transversales, recti, pyramidales, & quadrati lumborum, the *posterior inferior serrati*, the erectores spinæ, and, when the scapula is fixed, the *upper part of the serratus magnus*. *Nearly all the muscles of the body* may, however, assist in violent expiratory efforts.

Influence of the Nervous System over the Respiratory Movements.—Vide Physiology of the Medulla Oblongata & of the Pneumogastric Nerves.

THE ACT of BREATHING

Is accomplished *from* 14 *to* 18 *times per minute* in the adult, a little more frequently in extreme old age, about three times as often immediately after birth. Breathing is accelerated, however, by exercise, stimulants, great altitudes, moderate cold; it is a little quicker in females generally and in persons of small stature. The normal *ratio* between the number of the *respirations* and that of the *beats of the heart* is about 1 *to* 4 *or* 5 *in adult age*, and 1 to 3 or 3½ in childhood.

The complete respiratory act is divisible into three parts, *inspiration*, *expiration* & a period of repose or *pause*, the relative durations of which are respectively estimated by Dr. Burdon Sanderson to be *as* 4, 2, 9, the duration of the whole respiratory act being represented by 15. According to Dr. Sibson & Vierordt, however, inspiration is to expiration (pause included) as 10 to 14.

During *each respiratory act* an average of *from* 30 *to* 40 *cubic inches* of air (Ed. Smith) are *inspired and expired.* This volume of air is termed the **Breathing or tidal air.**

Complemental Air—Is the volume of air, about three or four times greater, or, on an average, *about* 120 *cubic inches* (Hutchinson), which can be *drawn into the lungs by a forcible inspiration.*

Reserve Air—Is the volume, on an average *from* 75 *to* 100 *cubic inches* (Hutchinson), which, though remaining in the lungs after an ordinary expiration, *may*, however, *be expelled by a* more *forcible effort.*

Residual Air—Is the volume, also, on an average, *from* 75 *to* 100 *cubic inches*, which still *remains in the lungs after the most violent expiratory effort.*

Comparing the amount of the breathing or tidal air with the total amount of the reserve air & the residual air, or, in other words, with the volume of air which usually remains in the lungs, it appears that *not more than* ¼ *or* ⅕ of this volume can be *displaced during each respiration.* It is only, therefore, the contents of the trachea, bronchi, and larger bronchial tubes that are mechanically expelled and replaced by fresh air. It is the *diffusive power of the gases* themselves that causes the renewal of the air in the smaller bronchial tubes and air-cells: the oxygen, which is more abundant in the larger tubes, diffuses itself towards the smaller passages and air-cells; the carbonic acid, which is more abundant in the air-cells and in the smaller tubes, and also the watery vapour given off from the mucous membrane, diffuse themselves in the contrary direction, or towards the larger bronchi & the trachea, from whence alone they are removed mechanically.

The *volume of air* which can be *expelled* from the lungs *by the fullest expiration, preceded by the deepest inspiration* of which a man is capable, is the measure of the **Vital capacity** of the chest (Hutchinson). In the male adult of the average stature of five feet seven inches the vital capacity is *about* 230 *cubic inches.* The vital capacity diminishes or increases with the stature by about 8 cubic inches for every inch in stature between the heights of five & six feet. It increases up to the age of thirty-five and then diminishes. In the female it is hardly more than ½ what it is in the male.

It is not proportionate to the size of the chest, or to the general muscular power of the individual, and is greatly diminished in pregnancy, and in all abdominal diseases. The value of its admeasurement as a means of diagnosis of the earlier stages of phthisis has, therefore, been exaggerated. A diminution of 16 per cent. appears, however, to indicate a diseased condition of the lungs.

The *total volume of air which passes through the lungs of a male adult in twenty-four hours* is estimated by Dr. Ed. Smith at *from* 700,000 *to* 1,700,000 *cubic inches, or from* 400 *to* 1,000 *cubic feet*, the quantity varying according to the amount of muscular exercise taken. The average quantity of air breathed *per minute* by a male adult *at rest* is, according to the same author, 500 *cubic inches in the day-time* and 400 *during the night.*

The *greatest force with which, in a male adult, the air can be drawn into the lungs*, is capable *of elevating a column of mercury usually about* 2 *or* 3 *inches*, sometimes as much as 6 or 7. When a column of mercury is elevated three inches, each square inch of the thoracic walls must support an atmospheric pressure of more than 23 oz.; adding to this pressure the elastic resistance of the thoracic walls, it is calculated that the *power then developed by the inspiratory muscles* must be *more than* 1,000 *lbs.*—The *force with which air can be expelled* from the chest is *about* 1-3*rd greater*, on account of the co-operation, during expiration, of the elasticity of the lungs and chest walls with the muscular effort. The power of the respiratory muscles is greatest in men of from 5 feet 7 inches to 5 feet 8 inches in height.

The *muscular force employed in ordinary inspiration* is calculated to be *about* 170 *lbs.* (Hutchinson.)

The entrance of the air into, and its exit from, the lungs produce the *respiratory sounds or murmurs*, which in health are of *two kinds:* the bronchial or tubular sounds, which are of a blowing character, and are best heard between the scapulæ and over the upper part of the sternum; and the vesicular murmur, which is heard as a gentle breeze all over the thorax.

The *rima glottidis* dilates in inspiration, as do also the *nostrils* when respiration is hurried.—The contraction of the bronchial tubes is believed to regulate, in accordance with the supply of blood, the quantity of air that the different parts of the lungs are to receive.

CHANGES of the AIR in RESPIRATION.

Expired air differs from inspired air in three respects :—
Its *temperature is raised;*
Its *degree of moisture is increased;*
Its *chemical composition is modified.*

Temperature.—Is *raised to nearly that of the blood,* especially in slow and tranquil breathing.

Degree of Moisture.—Expired air is *nearly saturated with watery vapour.*—The quantity of *water* thus *excreted* increases with the temperature of the atmosphere, and decreases as the atmospheric moisture increases; it *averages* 9 *or* 10 *oz. daily,* but may vary from 6 to 27 oz. Some of this water is probably formed in the respiratory process.

Chemical Composition.—Is modified by the *subtraction of oxygen* and by the *addition of carbonic acid, of a little nitrogen, and of various excretory principles.*—The *change is effected by* the process of *moist diffusion; the diffusion volumes of the oxygen and carbonic acid are, however, modified by the remarkable affinity of the blood for oxygen,* the former diffusion volume being increased and the latter diminished.

Oxygen.—5 *out of the* 21 *volumes of oxygen are abstracted from every* 100 *volumes of air. From* $\frac{1}{5}$ *to* $\frac{1}{7}$ of this amount *does not reappear in the carbonic acid expired,* but remains in the system where it combines with hydrogen to form water, and with the sulphur and phosphorus of the albuminoids to form the acids of the sulphates & phosphates excreted in the urine. The *amount of oxygen consumed daily determines that of the carbonic acid excreted,* and is similarly influenced by the same under-mentioned causes. It *averages* 40,000 *cubic inches* in a strong male adult.

Carbonic Acid.—*About* 4 *volumes only are added to the* ·04 *volumes already contained in every* 100 *volumes of air;* there is therefore at each expiration a loss of 1 per cent. of the air inspired.

It is calculated that on an average 32,000 *cubic inches of carbonic acid, containing about* 8 *ounces of carbon, are given off daily* through the lungs by a strong male adult of the average size. These quantities of carbonic acid & carbon are subject, however, to *considerable variations* due to the following causes.

Age.—The quantity of carbonic acid excreted *increases up to* 30 years of age, is *stationary from* 30 *to* 40, *decreases in old age.*—It is largest in children proportionally to the weight of the body.

Sex.—In females the quantity of carbonic acid excreted is less after the eighth year; it remains *stationary during the whole period of menstruation,* increasing temporarily, however, if menstruation be arrested by pregnancy or by any other cause; it increases for a time when menstruation ceases, and diminishes again in old age.

Muscular Exercise—*Increases the quantity of carbonic acid exhaled by* $\frac{1}{3}$ until an hour after the exercise has been relinquished (Vierordt); it *may increase it two, three, or fourfold* (E. Smith). The increase depends both on the increased amount of the air breathed, and on an increased per-centage of carbonic acid found in the expired air.—The quantity is diminished by prolonged exertion, occasioning fatigue.

Alimentation.—The quantity is *increased by good living & after meals,* especially when much nitrogenous food has been taken, and is diminished by fasting.—Tea, coffee, cocoa, pure alcohol, produce a sudden increase; certain liquors, such as brandy, whisky, gin, appear, however, to produce the reverse effect (E. Smith).

Temperature & Hygrometric State of the Atmosphere.—The quantity is *greatest in winter &* in cold climates, and *in damp weather.*

Time of Day.—The quantity *diminishes in the evening,* & is least at midnight; it *increases in the morning* until midday, when it appears to be as $1\frac{1}{4}$ to 1 when compared to what it is at midnight.

Purity of Air Respired.—The quantity *diminishes rapidly when the same volume of air is breathed over and over again,* the gaseous interchanges in the lungs entirely ceasing when the air contains 10 per cent. of carbonic acid, by which time it has lost about $\frac{1}{2}$ its normal quantity of oxygen.

Rapidity of the Respiratory Movements.—In abnormally *hurried breathing* the quantity *increases absolutely,* but it *decreases relatively* to the amount of air respired.

Nitrogen.—A *minute quantity,* about $\frac{1}{50}$ or $\frac{1}{100}$ of the quantity of oxygen consumed, *appears to be given off* from the lungs. The source of this small excess of nitrogen was at one time believed to be the nitrogenous elements of the food & tissues, a part of which elements were supposed not to be excreted with the urea, uric acid, & extractives of the perspiration, urine, & other secretions, but to be retained in the body until completely consumed or broken up by the respiratory process into their simple or primitive constituents. All the nitrogen of the food now appears, however, to be accounted for in the excretions, so that this nitrogen might be derived simply from the atmospheric air which is swallowed with the saliva, the food, & the drink.—*During prolonged fasting a minute quantity* of nitrogen *appears to be absorbed.*

Various excretory principles.—Expired air contains, in minute proportions, *several of the principles met with in the secretions of the skin & kidneys,* such as chloride of sodium, uric acid, urates of soda & ammonia. It also contains a nitrogenous organic compound, very prone to putrefy, and sometimes carbonate & hydrochlorate of ammonia and carburetted hydrogen; various odorous substances may be derived from the food and drink that are consumed.

CHANGES of the BLOOD in RESPIRATION.

Are the changes in *colour & temperature,* and in the *proportions of the fibrin, & of the gases.*

Colour.—It has been shown by Hoppe-Seyler & Professor Stokes, by means of the spectrum analysis, that the change of colour, which takes place in the lungs, from the dark purple of venous blood to the bright scarlet of arterial blood, and the reverse change, which takes place in the capillaries, are *due* respectively to the *oxidation & deoxidation of the hæmoglobin or cruorin*:—Dilute solutions of blood when examined with the spectroscope give rise to two dark lines or absorption bands, situated in the green and yellow of the spectrum between the D and E lines of Frauenhöfer. When a reagent capable of abstracting oxygen, such as protosulphate of iron or protochloride of tin, is added, the solution becomes darker in colour, and the two dark lines disappear in the spectrum and are replaced by a single broader band occupying an intermediate position between them. On exposing the deoxidised solution to the air it again brightens in colour, while, in the spectrum, the two first lines reappear; the alternate change may be repeated several times. The *hæmoglobin or cruorin* exists, therefore, *in two states of oxidation,* forming in the one case the *"purple hæmoglobin or cruorin,"* in the other the *"scarlet cruorin or oxy-hæmoglobin."* *Arterial blood* contains *more of the scarlet cruorin* and *less of the purple* than venous blood; *both kinds of blood, however,* contain normally *more of the former than of the latter,* for they both give rise to the two dark lines in the spectrum.

Temperature.—The *blood in the left side of the heart* was long believed to be warmer by 1° or 2° than that in the right; it is now known to be *about $\frac{1}{5}$th of a degree cooler.*

The Fibrin—Is *increased in quantity* in arterial blood, which, therefore, yields a firmer clot than the venous. The normal proportion of fibrin may be doubled in rabbits by causing them to breathe pure oxygen.

The Gases.—*Venous blood* contains, according to Magnus, but $\frac{1}{2}$ *as much oxygen* as, and $\frac{1}{4}$ *or* $\frac{1}{5}$ *more carbonic acid* than, the arterial.

ASPHYXIA. — DEATH by DROWNING.

Asphyxia.—The essential symptomatic characters of asphyxia are the *loss of muscular power and consciousness*, and the *cessation* of the *respiratory movements* & of the *pulsations of the heart*. Its essential pathological character is the *accumulation of dark blood in the right side of the heart and in the venous system generally*, which blood remains fluid for a long time.

The mode in which death occurs, though remaining essentially the same, differs slightly in the rapid and slower forms. In both cases the *first morbid process* is the *stagnation of the blood in the capillaries*.

In the *slower forms*, this stagnation *first* takes place in, or first shows itself *in*, the *systemic capillaries*. The *arteries and* the *left side of the heart* then become *distended*, and the *heart beats with greater power and frequency* to overcome the resistance.

In the *rapid form* the stagnation *first* takes place in, or first shows itself in, the *lungs*. The *heart* then *receives* but *little arterial blood* and soon *no arterial blood at all*.

Then, on the one hand, *the pulmonary artery*, the *right side of the heart* and the *venous system generally*, become *gorged with dark venous blood;* and on the other hand, the *nerve-centres*, the *muscular system* generally, and the *heart itself*, *no longer* receive their *due supply of arterial blood, and* they gradually *cease to perform their functions*.

Finally the *arteries, and* the *left side of the heart, empty themselves into* the *veins and* into the *right side*.

In cases of *recovery* from asphyxia *the process* just described *is reversed:* On the introduction of air into the lungs oxygen is once more absorbed and carbonic acid given off. The flow of blood through the capillaries of the lungs is then resumed under the influence of the pressure of the blood in the pulmonary artery and in the right side of the heart. Thus while the right side of the heart is unloaded and relieved the left side again receives its proper stimulus. The heart then resumes its action. The nerve-centres and the muscular system are restored. Respiratory efforts are now resumed, and consciousness and motor power reappear.

Drowning—Is *asphyxia with an additional obstacle to recovery*, viz., *the partial filling up of the air passages with water*, which obstacle prevents the reintroduction of air into the lungs when the body is brought to shore.—Animals *die much sooner from drowning than from simple apnœa*. In the experiments recently made by the Committee of the Royal Medico-Chirurgical Society it was found that the average duration of the respiratory efforts after simply plugging the trachea was about 4 minutes in dogs and 3 in rabbits, and that recovery might take place after deprivation of air for 3 minutes 50 seconds; immersion in water, however, for 1½ minutes was usually fatal.

Ordinary cases of *submersion in man are nearly always fatal after* 4 *or* 5 *minutes*, and *frequently after scarcely* 1 *minute*. *Recoveries have, however, taken place after* ¼ *of an hour*, and, it is said, even after ½ an hour; but in such cases it is probable that *syncope* took place upon falling into the water. Man would then be assimilated, with respect to drowning, to a hybernating mammal or to a cold-blooded animal, in both of which, the nutritive functions being less active, respiration may be suppressed without inconvenience for a considerable time; *complete intoxication* might produce the same effect. *Animals under the influence of chloroform*, and unable to make any violent inspiratory efforts, can resist submersion for a considerable time; so can, also, *newly born animals*, animals whose temperature has been lowered by several degrees, and animals in which the trachea has been plugged before they have been immersed.

Numerous experiments have been made with a view to ascertain the *best mode of treatment* in the case of drowned and asphyxiated persons: inflation of the lungs with hot air, oxygen, or ozone, injection of arterial blood, hot water, or vapour into the veins, galvanism, etc., may temporarily excite the action of the heart & of the respiratory muscles, but they all fail to restore life when the circulation through the lungs has been totally arrested. The *rules of the Royal Humane Society* very justly *recommend*, as the first means to be employed, the performance of *artificial respiration by Dr. Silvester's method*, that is to say, by *alternately pressing the arms against the sides of the chest and then raising them gently above the head fifteen times per minute*, while the patient is lying on his back.

EFFECTS of OVERCROWDING, and of BREATHING IMPURE AIR

Are *twofold,* and are respectively due:

1. To the *insufficient aeration of the blood;*

2. To the consequent *imperfect oxidation, elimination,* and *destruction, and* to the, therefore, *inevitable accumulation, both in the blood and in the surrounding atmosphere, of the effete organic substances arising from the disintegration of the tissues of the body, and from the disintegration of the absorbed products of the alimentation.*

I. Effects of the insufficient Aeration of the Blood.—The *absorption of oxygen & the elimination of carbonic acid diminish considerably, and morbid symptoms begin to appear,* when the air, through being previously vitiated by respiration, is charged with carbonic acid even to the apparently slight extent of ⅓ *per cent., or* 3 *parts in* 1,000 (Marshall). *When* the *air contains* 10 *per cent. of carbonic acid, in which case it has lost about ½ its normal proportion of oxygen,* it becomes *totally irrespirable,* and is immediately fatal to man.—The Black Hole of Calcutta was a room 18 feet square, having two small windows, in which room, in 1756, 146 prisoners of war were confined during one night: by the next morning 123 of them had perished. A similar occurrence, in which 70 out of 150 passengers perished, took place in the Irish steamer Londonderry in 1848.

The *morbid symptoms* appear to be *due not only to the insufficient supply of oxygen, but* also *to the* directly *poisonous effects of carbonic acid;* animals cannot live in an artificial atmosphere of carbonic acid and oxygen, in which the latter is contained in the proportion of 21 parts per 100, as it is in atmospheric air. After one bronchus of a tortoise had been tied by Rolando, the animal continued, apparently without any inconvenience, to breathe with the lung of the opposite side; the animal soon died, however, when pure air was allowed to enter one lung, and carbonic acid the other.

It is not enough for the purposes of life & health that a room be supplied once for all with the quantity of pure air that its inhabitants can consume during the time they remain therein; for the diffusion through the mass of the air of the room of the carbonic acid expired and the general diminution in the proportion of oxygen which would take place, would very soon interfere with the due aeration of the blood. For the same reason, it is not enough either *that minute by minute there should be withdrawn from the air of a room and replaced by pure air, as many times as there are individuals in the room, the volume of from* 400 *to* 500 *cubic inches of air* that is respired by each individual minute by minute. From about 20 to 40 times such an amount of air, that is to say, *from* 4 *to* 10 *cubic feet of air per minute* (which latter amount would yield an atmosphere containing about 15 parts of carbonic acid in 10,000), are *needed for each person.* In hospitals double that quantity is required.—A certain amount of *breathing space* ought also to be allowed. The general practice in England up to a recent date was to allow *not less than* 800 *cubic feet* of breathing space for each person; but *in Hospitals* 1,200 *cubic feet,* at least, ought to be allowed (Marshall).

II. Effects of the imperfect oxidation, elimination, and destruction, and of the inevitable accumulation both in the blood and in the surrounding atmosphere, of the effete organic substances arising from the disintegration of the tissues of the body, & from the disintegration of the absorbed products of the alimentation.—The *complete oxidation* of the effete products of organic disintegration transforms them into *carbonic acid, water, urea, uric acid,* and *other extractive matters,* which are all easily excreted through the lungs, skin, and kidneys. Their *imperfect oxidation* transforms them into those *numerous* but still imperfectly known *offensive products,* which Liebig compares to the soot or lamp-black of an ill-burning furnace or lamp.

These products *accumulate in the atmosphere of crowded cities, and, doubtless, also in the blood:* the proportion of animal matter in the air is in the town of Manchester 1 grain in 8,000 cubic inches, and on the hills above, 1 grain in 200,000 (Dr. Ang. Smith). Hence, in addition to a *depressing influence over the functions of the body generally,* that *peculiar liability to the zymotic diseases* under which labour the poor of our large towns, and also the unfortunate inmates of barracks, hospitals, workhouses, etc., where modern sanitary improvements have not yet been introduced.

APPENDIX

TO

RESPIRATION.

I.—THE RESPIRATORY CENTRE.

II.—RESPIRATORY & VASO-MOTORIAL UNDULATIONS OF THE BLOOD-PRESSURE CURVE.

III.—ASPHYXIA.

(Presupposes a knowledge of the Functions of the Medulla Oblongata.)

THE RESPIRATORY CENTRE.

Is its Rhythmic Action reflex, or is it Automatic?

It is essentially automatic; for, on the one hand, the facial & laryngeal muscles continue to dilate rhythmically both the nostrils & the glottis when all sensory impressions (save those that may reach the medulla through the cranial nerves) are cut off through division of the cord just below the medulla; and, on the other hand, division of all the cranial nerves, the pneumogastrics included, in no way arrests respiration. *But it is influenced reflexly* by sensory impressions continually ascending from the lungs through the pneumogastrics.

What keeps up this Rhythmic Automatic Action?

The continuous dearterialisation of the blood.

The more venous (or the less arterial) is the blood, the more active is the respiratory centre. – Venous blood "augments the natural explosive decompositions of the nerve-cells of the respiratory centre, which give rise to respiratory impulses" (Michael Foster). It quickens (slightly) their rhythm, and greatly increases their power, till ceasing to "confine themselves to their usual tracts, they overflow into others" (M. Foster), *i. e.*, excite to action, not only the ordinary inspiratory muscles, but also the extraordinary ones.

The more arterial is the blood, the less active is the respiratory centre. If for a few seconds we breathe more rapidly and more forcibly than usual (as divers do before they plunge), we may 'keep our breath' for a whole minute or more. If too vigorously carried on, artificial respiration soon induces *apnœa, i. e.*, a condition in which the animal does not breathe at all for a while, and the respiratory muscles are not only relaxed, but are unable to contract upon stimulation of the vagus. In apnœa, the hæmoglobin of the blood is saturated, or nearly saturated, with oxygen, and the want of breathing is not felt. Respiratory movements recommence, very gently at first, as the blood returns little by little to its ordinary condition.

How is the Respiratory Centre influenced Reflexly?

It is influenced by accelerating fibres which are continually at work, and by inhibitory fibres whose action is accidental.

The more important accelerating fibres run in the course of the pneumogastric nerves: Irritation of the central end of the divided pneumogastric accelerates the respiratory movements; and, if the irritation is sufficiently powerful, the respiratory rhythm may be so accelerated that at last the diaphragm is thrown into a condition of prolonged tetanus, and respiration is brought to a standstill in the extreme inspiratory phase. – Simple division of the pneumogastrics slackens the respiratory rhythm, but renders the respiratory movements proportionately deeper & fuller: what is lost in one direction is gained in the other, so that the nerve may be said to modify merely the distribution of the respiratory impulses in time,—normally, in the direction of greater frequency coupled with diminished energy,—when divided, in the direction of diminished frequency coupled with increased energy.

Inhibitory fibres run in the course of the superior laryngeal nerves. Irritation of one of these nerves slackens the respiratory movements, and, if sufficiently powerful, may bring them to a standstill in the expiratory phase; division of the nerve is, however, without any marked effect on respiration. – A few inhibitory fibres run also in the course of pneumogastrics: when the nerve is exhausted, its stimulation may retard or arrest the respiratory movements.

The inhibitory influences may be supposed to increase, and the accelerating influences to diminish, the obstacle opposed by the centre to the discharge of respiratory impulses. Increasing the obstacle, the former increase also the amount of energy that must be accumulated before the discharge can take place, and also, finally, the amount of energy discharged, *i. e.*, the force of the impulse. The latter, diminishing the obstacle, diminish also the amount of energy to be accumulated before the discharge, and therefore the energy of the discharge, *i. e.*, the force of the impulse.

Is it want of Oxygen, or excess of Carbonic Acid that causes Dyspnœa?

It is want of oxygen. Excess of carbonic acid (there being no deficiency of oxygen) acts as a narcotic poison, inducing drowsiness & coma, not dyspnœa. Respiration of a mixture of one part of hydrogen & four of nitrogen induces dyspnœa immediately, though the exit of carbonic acid by diffusion is no wise impeded.

Does the Dearterialised blood act Directly on the Medulla?

Yes. For suppresion of the circulation through the medulla (by ligature of the vessels of the neck) induces dyspnœa at once. So does also the artificial warming of the blood in the carotid artery.

RESPIRATORY & VASO-MOTORIAL UNDULATIONS of the BLOOD-PRESSURE CURVE.

(A note to "Force of the Blood in the Arteries.")

These undulations have a regular period, and their period is isochronous to, though not exactly synchronous with, that of the respiratory movements, the former period being somewhat in advance of the latter: The arterial pressure is at its lowest just after the commencement of inspiration; it rises during the remainder & greater part of the inspiratory movement and during the commencement of expiration, when it reaches its highest; it falls again during the remainder & greater part of expiration, and during the commencement of inspiration.

Normal Respiratory Undulations.

These are the mediate or indirect result of the variations of the intra-thoracic pressure.

The direct or immediate result of inspiration is to diminish the pressure both in the arteries & in the veins; and the direct or immediate result of expiration is to increase it.

The mediate, indirect, or final result is just the reverse. This happens as follows:–

The immediate result is most marked in the veins, whose walls are thinner than those of the arteries, and whose internal pressure is less. Hence a marked diminution of pressure in the veins during inspiration, a rush of blood to the heart, a heavier stroke of latter, and increased distension of the arteries, *i. e.*, increased pressure. – This result takes some little time to develop itself, as above stated.

The pulse-rate is quickened during the rise of the undulation, and slackened during its fall. This is due to the cardio-inhibitory centre being stimulated during the fall (probably in consequence of the previous rise), for if the vagi be divided on both sides, the variations in the pulse-rate are done away with without any change in the undulations.

Vaso-motorial Undulations. — Traube's Curves.

The vaso-motorial undulations are most clearly observed under two distinct circumstances, *i. e.*, when artificial respiration is substituted for normal respiration, and when all respiratory movements, both natural & artificial, have been stopped for a while. They are due to stimulation of the vaso-motor centre by the venous character of the blood.

During artificial respiration, the conditions of intra-thoracic pressure are reversed: The intra-thoracic pressure is increased when air is blown into the lungs, and diminished when it is allowed to escape. Curves similar in character to the foregoing, though less ample, are nevertheless observed under these altered conditions. They are still observed even when the chest is opened, the heart removed from the thorax, and an artificial circulation carried on by means of a pump.

When all respiratory movements cease (the animal being under urari, or its thorax being opened and artificial respiration being stopped), the blood-pressure rises steadily for a while, the blood-pressure curve presenting an uninterrupted ascent; but soon new curves, the so-called Traube's curves appear, large & sweeping in character. That both this rise and these new curves are due mainly, if not entirely, to stimulation of the vaso-motor centre, and to the consequent contraction of the small arteries, is shown by the fact that both phenomena are all but entirely suppressed when the spinal cord is divided just below the medulla.

If respiration is not speedily resumed, both the vaso-motor centre and the heart become exhausted through the increasing venosity of the blood. The undulations then disappear, and the blood-pressure again falls.

The rhythmic action of the vaso-motor centre is partly the result of rhythmic stimulation, and partly the result of its own rhythmic automatism. This is shown by the fact that, when Traube's curves occur, all rhythmic stimulation has ceased.

Vaso-motorial undulations probably complicate the respiratory undulations above described.

ASPHYXIA.

The Three Stages.

Asphyxia by sudden occlusion of the trachea runs its course in 3 or 4 minutes in the rabbit, in 4 or 5 in the dog. This course may be divided into three stages, as follows:–

1st Stage: – Dyspnœa or Hyperpnœa. – Lasts nearly a minute, and passes *gradually* into the second stage. At first, both inspiration & expiration rapidly increase in frequency, vigour, & the number of muscles called into play. The expiratory movements, however, soon become more marked than the inspiratory; and they predominate more & more.

2nd Stage: – Expiratory Convulsions – Rather shorter than the foregoing; passes *abruptly* into the third stage early in the second minute. The violent expiratory movements above mentioned culminate in expiratory convulsions, the order and sequence of which become more & more obscured by their increasing violence & extent. These convulsions are due to stimulation of the expiratory portion of the respiratory centre sometimes called the 'convulsive' centre, for they fail to appear when the cord is divided just below the medulla.*

3rd Stage: – Exhaustion; Inspiratory Convulsions; Collapse. – Occupies the remainder of the time. Calm suddenly follows the convulsions; for a time all movements cease; the muscles are relaxed & flaccid; the pupils are dilated & unaffected by light; irritation of the cornea induces no winking.

Inspiratory efforts now reappear, and become gradually more extended,—gasps deep & slow, followed by gentle expirations,—but also gradually weaker & separated by intervals which gradually lengthen. Mouth widely open, nostrils dilated, face drawn, head thrown back, extended limbs & trunk, etc., mark the few last efforts, each of which seemed final.

* They may be induced artificially by tying the carotids; similar anæmic convulsions sometimes occur after great loss of blood.

The Vascular Phenomena.

The blood-pressure rises rapidly during the two first stages, and attains a height far above the normal. The heart-beats are at first somewhat quickened; but they soon become slower, while at the same time they acquire considerable force: the pulse-curves are therefore very bold. During the third stage the arterial pressure falls rapidly and becomes less during inspiration than during expiration, and the heart's action is greatly weakened. The beats continue, however, a few seconds after the respiratory movements have ceased.

Explanation of the Vascular Phenomena.

The rise of the blood pressure during the first & second stages is due to the contraction of the small arteries, and also, perhaps, at least at the very first, to the increased action of the heart induced by the first exaggerated respirations (inspirations). This contraction of the small arteries is due to stimulation of the vaso-motor centre by the venous character of the blood, and perhaps also to some extent, to direct stimulation either of the peripheral vaso-motor mechanisms or of the muscular arterial coats.

The first exaggerated respirations (inspirations) explain the early acceleration of the heart's action. The continued exaggerated respirations (inspirations) explain the subsequent retardation: distension of the cavities of the heart was first favourable to the heart's action, but, when pushed too far, it becomes injurious; this is shown by the fact that the heart-beats frequently recommence for a time when the distended veins are pricked & are thus partly emptied. The retardation of the heart's action is further attributable to stimulation of the cardio-inhibitory centre contained in the medulla: division of the vagi renders the retardation less pronounced. This stimulation of the cardio-inhibitory centre further explains the increased energy of the beats, which at first accompanied their retardation: the longer it takes to generate the impulse, the stronger the impulse must be.

The fall of the arterial pressure during the third stage is due to several causes: to stimulation of the cardio-inhibitory centre, to exhaustion of the muscular fibres of the heart through deficiency of arterial blood and over-distension, and, towards the close, to dilatation of the arteries through exhaustion of the vaso-motor centre. The fall of the pressure during each inspiration is the necessary result of the non-compensation, by the usual increased cardiac action, of the general diminution of intra-thoracic pressure which is the immediate result of the thoracic enlargement.

ANIMAL HEAT.

ANIMAL HEAT.

The production of animal heat is a *universal function* throughout the entire animal kingdom, and animals have been divided according to their usual temperature into *warm-blooded*—mammalia & birds; and *cold-blooded*—fishes, amphibia, reptiles, and the invertebrata.

The *temperature of warm-blooded animals* is relatively *high*, and, though different in the various species, is very *nearly the same in each species under all normal conditions of life* it being almost independent, within the limits of the climateric variations, of the temperature of the surrounding medium.

The temperature of *cold-blooded* animals is relatively *low*, and *varies with*, and nearly to the same extent as, *that of the surrounding medium*, being, however, in all usual circumstances, higher than that of the medium by a certain number of degrees, which number is the same in all animals of the same species.

The second of the two correlative terms above used—"warm-blooded" & "cold-blooded"—is, therefore, in one sense incorrect. So is also, in another sense, the second of the two designations more recently proposed by Bergman, viz. "*animals of constant temperature*" & "*animals of variable temperature*;" for though the temperature of the latter varies absolutely, its surplus over and above that of the surrounding medium, which surplus is due to individual production of heat, is relatively invariable. The two correlative terms the Author would propose are those of "*Animals of high & completely individual temperature*" and "*Animals of incompletely individual & usually low temperature.*"

Average Animal Temperatures.

Temperature of Warm-blooded Animals, or Animals of Constant Temperature, or of High & Completely Individual Temperature.

Birds .. .. 100° to 108°, or even 111° in the small species;
Mammalia 97° to 104°.

Surplus of Temperature over & above that of the surrounding medium in Cold-blooded Animals, or Animals of Variable Temperature, or of Incompletely Individual & usually Low Temperature.

Reptiles .. 7° to 15°;
Amphibia .. ½° to 1½° in summer, and 2° to 3° in winter;
Fishes usually ½° to 1°, sometimes 2° to 3°, in the tunny & bonito, 18°.

Average Temperature of the Different Parts of the Human Body.

AVERAGE TEMPERATURE OF THE BLOOD, 100° to 102°.—In the peripheral parts of the body the *blood in the veins* is *cooler* than that in the arteries by 1° *in the deep veins, by several* degrees *in* the *superficial ones;* in the deep or central parts of the body the difference is usually but slight. The blood in the *renal veins* is, however, considerably warmer than that in the renal arteries, and the blood in the *hepatic veins* is not only *warmer* than that in the portal vein, but it is warmer by 1° than that in the aorta (Bernard); the blood in the *right side of the heart* is 1-5*th*° *warmer* than that in the left.

AVERAGE TEMPERATURE OF THE ORGANS & TISSUES, 98° to 100°.—It is always lower than that of the blood, and varies according to vascularity, distance from central parts, proximity to the surface, and degree of exposure:

Temperature of the Abdomen (taken in the bladder) 102°;

Thorax	Rather lower on account of the heat lost by expired air.
Rectum	100°;
Mouth (under the tongue) ...	98°;
Axilla	96°;
Hands & feet	90°.

CONDITIONS WHICH MODIFY the TEMPERATURE of the BODY.

The temperature of the body is, within very narrow limits however,
Elevated by external heat, exercise & good living;
Depressed by cold, inaction & bad fare;
Variously influenced by time of day, age, sex, & disease.

External temperature.—The *extreme, climateric variations,* though they range from −70° in the arctic to +130° in the tropical regions, *do not influence the temperature of man to the extent of more than 3° or 4°,* provided he have, on the one hand, command over food & raiment, and provided he can, on the other hand, protect himself against the direct rays of the sun. This stability of the bodily temperature is *due,* in the one case, *to* the *power of producing a greater amount of heat* by an increased activity of the respiratory functions, and by a greater consumption of calorifacient food, and, in the other, to the *loss of a great amount of heat by the continual evaporation of the profuse perspiration,* with which, in hot climates, the skin is constantly moistened. All warm-blooded animals also possess, but to a less and variable extent, the power of maintaining their normal temperature in very different latitudes and under great variations of external temperature.

This *power of maintaining a uniform temperature has, however, its limits,* and the experiments of Magendie & others have shown that *animals die rapidly when submitted to degrees of heat or cold capable of raising their temperature about 9° or 10°, or of lowering it about 20°.*—Large bodies of troops, and even whole armies have thus been "frozen to death," especially when overcome by fatigue, or when ill-fed, ill-clad & ill-protected.—The *contact of excessively hot dry air can* however *be borne* by man *for short periods:* Sir Ch. Blagden & others have supported for a few minutes temperatures of 198°, 211°, 260°, 284°, and a man named Chabert has penetrated into ovens heated to from 400° to 600°; when however the air is moist, so as to prevent evaporation from the surface of the skin, a temperature of 120° very soon becomes unbearable.

Exercise.—Prolonged muscular action elevates by one or two degrees the temperature of the contracting muscle. Exercise, however, *elevates* but *slightly* the *general temperature of the body,* but it may, by quickening the circulation, raise by several degrees the lowered temperature of the extremities.—Inaction produces the contrary effect, and *during sleep* the *temperature falls 1° or 2°.*

Food.—*Good living keeps up a high bodily temperature,* but the immediate effect of a full meal is to lower the temperature a little.—Stimulants produce a slight immediate rise in the temperature.—*Bad fare depresses the temperature,* and diminishes the power of resisting cold.

Time of Day.—The *temperature* is *highest in the morning,* varies slightly during the day, falls in the evening, and is *lowest towards midnight.*

Age—*Modifies the temperature but slightly*; the temperature of children is, however, about 1° higher, and that of the aged a trifle lower, than that of the adult. But the power of the very young and of the aged to resist the action of cold is much less than that of the adult.

Sex.—Its *influence* is *very trifling* indeed, and it has frequently been denied. It is believed, however, that the average temperature of the female is a trifle lower than that of the male.

Disease—Influences the temperature of the body more than any other cause the *temperature rises* considerably *in* all *febrile affections* and often reaches 106° or 107° in scarlatina & typhus, & sometimes 111°. It is *depressed in* cases of *syncope & apparent death,* in the *morbus cæruleus* or blue disease, and in *cholera,* in the stage of collapse of which latter disease it is often lowered to 77° or 79°.

THE SOURCE of ANIMAL HEAT.

The French chemist Lavoisier, the discoverer of the composition of air, propounded the first scientific theory of the production of animal heat, which is the chemical theory now universally received.

Before Lavoisier, the production of animal heat was referred to the various movements which take place in the body & to the consequent *stretchings & recoilings of the several tissues,* to *friction* generally, and in particular to the friction of the blood against the walls of the blood-vessels, and to *the influence of the nervous system & of the so-called vital force.*

The theory of Lavoisier, though received in its main traits, must however be corrected or supplemented in two points: the union of oxygen with carbon & hydrogen does not take place solely, or even principally, in the lungs; and the nervous system, though its action cannot now be considered as the primary source of animal heat, governs the chemical changes upon which the production of animal heat depends, and thus modifies the production of heat both locally and generally.

The chemical theory of animal heat, as it now stands, is that the *oxygen taken into the blood at the lungs combines in the circulatory system, and more particularly in the capillaries, with the carbon and hydrogen, and* also with the small amount of *sulphur and phosphorus,* both of the *disintegrated tissues &* of those *elements of the food,* termed calorifacient, which are not, or which are but partially, transformed into tissue; and that such combination, or combustion, is the real & true source of the heat of the body.

That such combination does take place appears evident from the facts that an *average-sized* male *adult absorbs daily about* 40,000 *cubic inches of oxygen,* and *excretes* in the same time by his lungs, skin, & kidneys, *about* 32,000 *cubic inches of carbonic acid gas & from* 75 *to* 95 *ounces of water, of the disposal of which oxygen, and of the origin of which carbonic acid & of no less than* 3 *or* 4 *ounces of which water, no account can be given, if it be not admitted that such combination takes place,* and that the above-mentioned quantity of carbonic acid & the three or four surplus ounces of water are the products thereof.

That such combination, or respiratory combustion, as it is now termed, is the source of animal heat is rendered more than probable by the fact that the *direct combination with the above-mentioned quantity of oxygen, of the quantities of carbon & hydrogen necessary to produce the above-mentioned quantity of carbonic acid & the above-mentioned surplus of water would give off very nearly the quantity of heat generated in the body in* 24 *hours*;—and by the fact that the whole amount of caloric generated in the body can be accounted for by taking into consideration the *heat evolved by the combustion of the sulphur and phosphorus* (to which combustion is due a part of the acids of the sulphates and phosphates excreted in the urine) and *a few additional sources of heat,* such as the heat produced by those imperfect or incomplete combustions which give rise to the formation of urea, uric acid, and the various extractive matters found in the urine and other secretions, and also by taking into consideration the fact that more heat is produced by the combustion of certain alimentary compounds than would be produced by the separate combustion of their component parts.

The experiments, upon the results of which the above assertions are based, were begun by Lavoisier by means of his ice calorimeter, continued by Dulong & Despretz, and completed by the experiments of Liebig and by those of Fabre & Silbermann upon the combustion heats of carbon & hydrogen.—Lavoisier overlooked the combustion of hydrogen, taking into account the combustion of carbon only; he thus explained the production of but $\frac{5}{6}$th, of the heat evolved in the body.—Dulong & Despretz took into account the combustion of both carbon & hydrogen, but they underestimated the combustion-heats of carbon and hydrogen; they thus explained the production of $\frac{8}{10}$ths or $\frac{9}{10}$ths of the heat evolved in the body. Liebig arrived at the above-mentioned results by repeating the experiments of Dulong & Despretz, and by using in his calculations the more accurate numbers given by Fabre & Silbermann to represent the combustion heats of carbon & hydrogen.

Collateral evidence in support of the chemical theory of animal heat *is derived from the observation of the different physiological habits & corresponding average temperatures both of animals & of man, thus:*

1. The *division of the animal kingdom into warm and cold-blooded animals,* or into animals of constant & animals of variable temperature, corresponds to the relative activity or inactivity of the nutritive & respiratory functions, and to the amount, relatively great in the one case, very small in the other, of carbonic acid given off through the respiratory organs;

2. The *mean temperature of the different classes of warm-blooded animals, and* the *mean surplus of temperature over & above the temperature of the surrounding medium observable in cold blooded animals,* correspond likewise to the greater or less activity of the above mentioned functions: the temperature of birds is higher than that of the mammalia; that of reptiles is higher, under similar climateric conditions, than that of the amphibia, the temperature of which latter is higher than that of fishes & and of the invertebrata;

3. In warm-blooded animals the production of heat, and the activity of the nutritive respiratory functions, are similarly affected by the various conditions of *age, sex, alimentation, muscular activity, external temperature or season, time of day & purity of inspired air,* both being increased to a maximum in young well fed, active males, during cold & dry days & seasons and in open air, and both being reduced to a minimum by the contrary conditions and during sleep and hibernation;

4. The *temperature of any one part of one of the higher animal organisms,* and the temperature of the blood in the same, is greatly dependent upon the activity of the chemical processes of which such part is the seat: the highest temperature observable in the mammalia occurs in the liver and in the hepatic veins.

INFLUENCE of the NERVOUS SYSTEM over the PRODUCTION of ANIMAL HEAT.

The action of the nervous system with regard to the production of heat is reduced under ordinary circumstances to the *governing influence* it exerts *over the action of the heart, and over the arterial circulation by vaso-motor reflex action, and to its consequent indirect influence over the chemical processes of nutrition.*

That the *vaso-motor nerves of the sympathetic system govern the arterial circulation and,* among other processes, the *heat-producing process,* is superabundantly proved by the results of the *division of the cord of the sympathetic in the neck, or* those of the *removal of the superior cervical ganglion:* the corresponding side of the face then becomes greatly congested, and its temperature rises by several degrees; irritation of the peripheral portion of the sympathetic causes the part to resume its normal appearance & temperature (Bernard).

That *such influence is exerted by reflex action,* and also that such reflex action has an especial bilateral character, is proved by the following facts—viz., when a *freezing mixture* is *applied to the ulnar nerve at the elbow,* the temperature of the two inner fingers, which momentarily falls, subsequently rises by several degrees; *if one hand, or the extremity of the wing of a bat, be immersed in the same mixture* the temperature of the other hand, or of the corresponding point of the other wing, will be lowered at the same time as that of the immersed part, no change of temperature taking place elsewhere (Brown-Sequard).

The *temperature of a limb falls* therefore *after the division of its nerves, or of the posterior roots of the same,* on account, probably, of the then suppressed centripetal conveyance of the sensory impressions by which dilatation of the arteries is called for: paralysed limbs are known to be cold.

Division of the nerves of a limb close to their exit from the intervertebral foramina produces, however, the *contrary effect,* on account of the simultaneous division of the sympathetic fibres, which have just joined the nerve from the neighbouring ganglion (Bernard).

The administration of *narcotics, shock, severe injury to the nerve-centres,* occasion a *general fall of the temperature of the body* on account of the above sensory impressions being no longer perceived by the nerve-centres & on account of their being no longer reflected upon the vaso-motor nerves.—*Severe injury to, or division of, the spinal cord* appears *however* to produce a *temporary elevation of the temperature of the parts below;* so does also the section of the anterior roots of the spinal nerves (Bernard).

DIGESTION.

P.

FOOD — 1st Tablet.

Food is any substance, which, taken into the system by the alimentary canal, becomes subservient to either or both of the two following purposes, viz., on the one hand the *nutrition of the tissues and the supply of materials for the various secretions ;* on the other hand the *production of heat & the maintenance of the vital forces.*

Food must consist of *organic substances,* that is to say of substances having formed part of a living organism and containing *several proximate organic principles, various complex chemical compounds, water & saline matters.* — Chemically pure proximate organic principles, whether taken separately or together, cannot be looked upon as normal food, and have even been considered of late years to be incapable, when taken separately, of maintaining life (Liebig, Lehmann) ; which latter belief is however unfounded as regards the nitrogenous proximate organic principles (Savory).

The various articles of food are mainly subservient to the one or the other of the two above mentioned purposes, according to their containing a large amount of *nitrogen* or a large amount of *carbon or of carbon & hydrogen,* and may consequently be divided into *nutritive or plastic,* and *calorifacient or respiratory.*

Animal food in general contains an *abundance,* and *vegetable food* a *relatively small amount, of nitrogen.* In the usual mixed diet of man the former is therefore principally *plastic,* the latter principally *calorifacient.*

The proximate organic principles of animal & vegetable diets are however the same, the only difference between the two diets lying in the different proportion in which they contain the nitrogenous & the non-nitrogenous proximate organic principles.

THE PROXIMATE ORGANIC PRINCIPLES of FOOD.

The nitrogenous proximate organic principles constitute, chemically speaking, a very homogeneous group, and may be termed collectively the *albuminoid* principles; they contain the four essential constituents of organic matter, carbon, hydrogen, oxygen & nitrogen. The most important are *albumen, fibrin, syntonin, casein, gelatin,* derived from the animal, and *gluten & legumin* derived from the vegetable kingdom.

The non-nitrogenous proximate organic principles contain but carbon, hydrogen & oxygen. They form, chemically speaking, two groups, that of the amylaceous & that of the oleaginous principles.—The most important of the proximate organic principles of the *amylaceous* group are starch, sugar, alcohol, & their allies. The *oleaginous* proximate organic principles are olein, stearin, margarin, & the vegetable oils. — The richest of the non-nitrogenous proximate organic principles both in carbon & hydrogen, and consequently the most highly calorifacient are the fats & the alcohols.

The *non-nitrogenous* proximate organic principles, when taken alone, *cannot maintain life;* dogs fed exclusively on either gum, sugar or oil (with water) emaciate rapidly, and die on an average about the 30th day, presenting the appearances produced by starvation (Magendie). Geese similarly fed live but from sixteen to twenty days, and lose from one-sixth to one-eighth of their weight (Tiedemann, Gmelin).

The *nitrogenous* proximate organic principles, when taken alone, have also been believed of late years to be incapable of maintaining life (Leibig, Lehmann) : A goose fed with whites of eggs died on the forty-sixth day, dogs fed exclusively on either albumen, fibrin or gelatin did not live much longer (Tiedemann, Gmelin); when fed however on the three substances combined, so as to prevent loathing & disgust, they lived as long as three months. — Recently animals have been made to live for a considerable time in apparent health, on purely albuminoid substances (Savory). Their temperature remained unchanged. The nitrogenous or plastic proximate organic principles are therefore calorifacient also, at least when the non-nitrogenous are wanting. Are they calorifacient by being first *transformed in part into a non-nitrogenous ternary compound,* or is it *the direct combustion of the tissues, which they form,* that gives rise to the formation of heat? Both views are probably correct.

FOOD — 2nd Tablet.

WHAT, and HOW MUCH REQUIRED.

To maintain *both life & health* the food must contain *both nitrogenous & non-nitrogenous* proximate organic principles, and must contain the former *in quantity sufficient to compensate for the waste of the tissues* and the latter in quantity sufficient *to generate enough heat to maintain the normal temperature of the body;* – in other terms the food must correspond to the excreta both in quality & quantity. — It is indifferent what these proximate organic principles be, and whether they be derived from the animal or from the vegetable kingdom.

A strong man excretes daily in temperate climates about 10 *oz. of carbon* and rather more than ½ *oz. of nitrogen.*

Now *bread* contains about *30 per cent. of carbon* and *1 per cent of nitrogen*, and *meat* about 10 *per cent. of carbon* and a little more than *3 per cent. of nitrogen.* To obtain the necessary amount of nitrogen from *bread alone* a man would have to eat about *4 pounds* of bread a day, and would then be taking *twice the quantity of carbon he requires;* to obtain the necessary amount of carbon from *meat alone* a man would have to eat about *6 pounds* of meat a day, and would then be taking about *six times as much nitrogen as he requires.*

A *combination* of bread & meat would therefore be *advantageous;* thus

Bread	2 lbs., and
Meat	12 oz.

would supply the necessary quantity of carbon & hydrogen (Béclard).

Fatty matters being added to the diet, the proportion of bread may be diminished; thus a very fair diet is the following:

Bread	1¼ lbs.
Butter	¼ lb.
Meat	1 lb. (Dalton).

Playfair recommends a little more farinaceous food and a little less fat. — In both diets a little more meat is prescribed than appears to be needful for the majority of individuals.

In cold climates more food, and more of the more highly calorifacient food, is required, and *fats & alcohols* are much sought for. The inhabitants of *hot climates* are on the contrary abstemious, and live principally on vegetable diet.

In actual practice, however, much must depend on the *taste & digestive powers* of the individual, and frequent changes of diet are required to prevent loathing & disgust. A regular supply of fresh vegetables is also necessary to avoid the development of scurvy.

These laws of alimentation are *carried out in*, and are admirably *illustrated by*, the composition of *milk*, the typical food prepared by nature for the young of the mammalia, and of the yelk & the albumen of *eggs*, the first source from which nutriment is derived for the embryos of the ovipara.

Milk contains:

WATER	9-10ths;
SOLIDS	1-10th, of which solids
SUGAR forms *about*	1-half;
CASEIN	1-3rd;
BUTTER	1-4th;
SALTS	1-50th.

Eggs contain:

WATER	4-5ths;
SOLIDS	1-5th, of which solids
OIL (principally in the yelk) forms *about*	1-half;
ALBUMEN (equally in yelk & white) ...	1-half;
SALTS	1-20th.

THE SALIVA

Is *clear colourless* & *alkaline* when collected pure by means of a fistula from one of the larger glands; it is *thin & watery* when collected from the *parotid* gland, *thick & viscid* when collected from the *submaxillary* or the *sublingual.* Its average density is from 1002 to 1009; its temperature is 1° or 2° higher than that of the blood. – The *thick & frothy fluid* usually found *in the mouth* is a *mixture of saliva & mucus*; during the intervals of meals, when the mucus predominates, this fluid ceases to be alkaline, and sometimes it even becomes acid.

Saliva contains 994 parts of *water* per 1000, *sarcode-like bodies* endowed with the power of spontaneous movement, *epithelial-cells, mucus, fatty matters, salts,* – among which is a little *sulpho-cyanide of potassium,* which strikes a deep red colour with a persalt of iron, – also an azotised substance, *salivin or ptyalin,* to which the chemical properties of saliva are principally due.

The purposes served by saliva are:

A. Mechanical – It keeps the *mouth* in a *due condition of moisture,* and dissolves sapid substances, which are thus rendered perceptible to the taste. The *fluid saliva from the parotid* on being *mixed with the food* during mastication transforms it into a *soft pulpy mass;* this mass becomes *coated* with a *layer of the more viscid fluid* secreted by the *submaxillary & sublingual* glands, and is then easily swallowed.

B. Chemical – It *transforms starch* first into *dextrin,* & then into *grape-sugar, which latter is soluble, & capable of being absorbed:* on being mixed with saliva, starch paste soon ceases to produce its characteristic blue colour when iodine is added, or it becomes colourless if previously coloured; if boiled with an alkaline solution of tartrate of copper, it now throws down the reddish precipitate of the oxide. This transformation takes place *partly in the mouth* and *partly in the stomach,* where, however, it is probably retarded by the acidity of the gastric juice; it is subsequently *resumed in the small intestine* under the influence of the pancreatic juice & perhaps also of the intestinal fluid. It is *especially the mixed saliva found in the mouth* at meal times, and also the saliva from the parotid gland, that have the power of thus acting upon starch. – The saliva *acts catalytically,* i.e., by mere presence, and its influence upon starch is of a continuous nature resembling that of a ferment: an extremely small proportion of ptyalin will convert into sugar an almost indefinite quantity of starch, 2000 times its own weight (Mialhe).

No other substance, except pancreatic juice, and perhaps also the intestinal fluid, is capable of transforming starch into dextrin & grape-sugar with anything like the same rapidity as saliva; the same transformation is however effected, but much more slowly, by most *azotized substances in a state of incipient decomposition.*

Saliva has little or no action either on the oleaginous, or on the albuminoid constituents of the food.

The saliva is *secreted most abundantly during meals,* and *when food* is *directly introduced into the stomach* through a gastric fistula. Mental stimuli resulting from the sight or thought of luscious food, the presence in the blood of mercurial salts, mastication, etc., will also accelerate the flow of saliva. – The *quantity* of saliva usually secreted during the *twenty-four hours* may be estimated, on an average, at *from* 1 *to* 3 *lbs.,* the quantity *increasing with* the degree of *hardness & dryness of the food.*

The degree of secretory activity of the salivary glands corresponds with their vascular condition for the time being, though it is not solely dependent upon this one condition: the *glands when at rest* are *but slightly vascular,* and the small amount of venous blood returning from them is dark; when they are *in a state of activity,* their *vessels* are *distended* by an *abundant flow of blood,* and, in the veins, the blood is scarlet and the current pulsatory.

The salivary *secretion* is *governed* therefore, at least to a great extent, by *vaso-motor reflex action,* the *afferent nerves* being the *gustatory* & the *glossopharyngeal,* and the *motor* influence being derived from the *facial,* and being conveyed to the submaxillary & sublingual glands through the *chorda tympani* & the efferent branches of the submaxillary ganglion, and conveyed probably, to the parotid, through the otic ganglion & the auriculo-temporal nerve: – *division of the chorda tympani or of the facial* nerve greatly *diminishes* the *salivary secretion; irritation* of the *distal end* of the divided nerve *again excites it; removal of the submaxillary ganglion entirely arrests it* (Bernard). The action of the *sympathetic* nerve appears to be the reverse of the foregoing: *division* of the sympathetic in the neck (where alone it can well be effected) or removal of the superior cervical ganglion, produces among other results, an *increase* of the vascular & secretory activity of the salivary glands; *irritation* of the same nerve *diminishes* both and renders the secretion *thick & scanty,* and *rich in* the above mentioned *sarcode-like bodies.* – It must be added however that either the *cerebro-spinal or* the *sympathetic* nerves, *or both,* exercise *probably* some *additional & direct influence upon the gland-cells* themselves (V. physiology of the sympathetic).

DEGLUTITION, or the ACT of SWALLOWING

May be divided into *three parts or acts*, which take place respectively in the *mouth*, the *pharynx*, & the *œsophagus*. The first act alone is under the control of the will; the two others take place by an incontrollable reflex action.

First Act – The masticated morsel glides backwards between the tongue & the hard palate, the tongue being pressed against the hard palate successively from tip to base.

Second Act – The hyoid bone, which is *the connecting link between the larynx, the pharynx & the tongue*, is suddenly raised by its elevator muscles; the stylo- and palato-glossi & -pharyngei acting at the same time directly upon the tongue & the pharynx. The three organs are therefore elevated: the *pharynx* is raised vertically; the *tongue*, especially its base, is drawn upwards & backwards; the *larynx* is drawn upwards & forwards. – In consequence of the displacement of the two latter organs, the epiglottis is pressed against the base of the tongue, and is inclined over the superior aperture of the larynx.

At the same time the *soft palate* is *tensed* in its upper part by its tensors & *raised* in its lower & central part by its levators, and *its pillars* are *drawn together* by the action of the palato-glossi & -pharyngei, the upper or respiratory part of the pharynx being thus shut off from the lower or alimentary part.

By this mechanism: –

1. The morsel is *propelled into the pharynx*.
2. It is *precluded from entering the larynx*. – It will be observed that the superior aperture of the larynx being protected by its being brought forwards under the base of the tongue, the lowering of the epiglottis over it is to a certain extent unnecessary. As an additional protection, however, not only does the epiglottis cover over the aperture of the larynx during the second act of deglutition, but, in the interior of the larynx, the glottis itself also closes at the same moment.
3. The morsel is *prevented from ascending towards the Eustachian tubes & the posterior apertures of the nares*.

The *contracted muscles now relax*. The pharynx immediately resuming its previous position, the morsel of food is quickly carried downwards towards the œsophagus; it is also hurried on by the action of the constrictors of the pharynx which contract behind it.

Third Act – The food is carried through the œsophagus by the *peristaltic action* of the latter. This consists in the successive contraction of the longitudinal fibres around the morsel of food and of the circular fibres behind it. Both actions combine to cause progression, the one, by drawing over the morsel the portion of the tube into which it has not yet penetrated, the other by propelling the morsel onwards.

THE GASTRIC JUICE

Is *clear, viscid, amber-coloured, acid,* nearly inodorous, & of a specific gravity of from 1002 to 1005.

It contains 994 parts of *water* per 1,000, *alkaline & earthy chlorides & phosphates,* and an azotised substance called *pepsin,* to which latter, conjointly with a *free acid,* its physiological properties are principally due. – It is still a debated point whether this free acid is *lactic acid,* as is maintained by Chevreuil, Lehmann, Bernard & others, or whether *only a small part of it is lactic acid, & the remainder hydrochloric acid,* as is generally believed by english physiologists : – hydrochloric acid is the acid obtained from gastric juice by distillation; that is however but an insufficient proof that this hydrochloric acid is the free acid of the gastric juice, for were the free acid lactic acid, hydrochloric acid would nevertheless pass over among the products of distillation, since the lactic acid, when heated, decomposes the chlorides & sets the hydrochloric acid free. Professor Graham was able to separate by his method of liquid diffusion a considerable proportion of hydrochloric acid & a small proportion only of lactic acid from a fluid, apparently gastric juice, vomited in large quantities in a case of sarcina ventriculi. Other acids, such as acetic & butyric acids, are also found in the stomach during digestion.

The *acid* is *formed in the most superficial layers of the mucous membrane,* the *pepsin in the cells of the peptic follicles;* and the two are *mingled together only when discharged into the stomach:* – when lactate of iron & ferrocyanide of potassium are injected separately into the jugular vein, no discoloration takes place in the tissues & fluids generally on account of their alkalinity, but on the surface of the mucous membrane, and on the surface alone, the blue tint of the ferrocyanide of iron rapidly appears (Bernard); – when the stomach has been thoroughly cleansed by careful washing till no trace of acidity remains, a fresh supply of pepsin, no longer acid but neutral, may still be obtained by further maceration.

The *quantity of gastric juice secreted daily* varies probably from 1·20th to 1·15th or 1-10th of the weight of the body, or *in man from* 10 *to* 20, *and sometimes* 30*lbs.* It is *only when food* or some foreign substance is *introduced into the stomach* that the gastric juice is secreted, the mucous membrane becoming at the same time reddened & turgid; the mucous membrane, when at rest, is pale, and its secretion is alkaline.

The process is doubtless *governed* by *vaso-motor reflex action,* but it is in no wise clearly made out what are the respective influences upon it, of the pneumogastric & sympathetic nerves. *Division* of the *pneumogastrics* in the neck *puts a stop to digestion* (Bernard), the process, however, being subsequently restored (Reid); the suspension of the process being due either to the paralysis of the muscular fibres of the stomach (Longet), or to the disturbance of the respiratory function through the suppressed action of the pulmonary branches of the pneumogastric (Budge). Irritation of the sympathetic stops the secretion, says Bernard; the *division* of the *splanchnic nerves* & the *removal of the semilunar ganglia* by Budge, Schiff & others produced however but *little or no effect.*

The gastric juice *softens, reduces into pulp and finally dissolves* the *albuminoid principles of the food transforming them,* first into a series of intermediate & variable products termed para-, meta-, & dyspeptones, & *a, b, c,* peptones (Meissner), and transforming them finally into one definite product, the true *albuminose or peptone.* This latter has the *same chemical composition as white of egg,* and is very nearly identical, from whatever albuninoid substance it be derived. It is *soluble* in all proportions in water, *very diffusible,* and it rotates the plane of polarized light to the left. It is *no longer coagulable by nitric acid or by heat,* though still precipitable by metallic salts, strong alcohol & tannic acid. – The para-, meta-, & dyspeptones & *a, b, c,* peptones differ from each other & from the definite or true peptone mainly in their relative solubility in neutral & acid solutions, and in their precipitability by nitric acid & by ferrocyanide of potassium.

Gelatin & gelatin-yielding tissues are acted upon but slowly by the gastric juice, and the fluid resulting from their solution retains for some time its power of solidifying. Gastric juice has *little or no action on either the amylaceous or the oleaginous constituents* of the food.

These statements are proved by the observation of *artificial digestions,* conducted either by means of gastric juice obtained through a gastric fistula, or conducted by means of an artificial digestive fluid, which may be prepared by macerating in water a portion of the mucous membrane of the stomach of a pig or of the rennet-bag of a calf, sheep, or ox, and then adding a little hydrochloric acid; it is also proved by the results of natural digestion both in the stomach of animals killed a short time after a meal, & in that of patients afflicted with an accidental gastric fistula. – The *stomach does not digest itself* on account of its walls being *saturated with the alkaline salts of the blood* circulating in its capillaries: – if its arteries are tied, the stomach is soon destroyed (Pavy), as it is after death when death occurs during the digestive process.

Certain *conditions* are *necessary to the action of the gastric juice* or to that of the artificial digestive fluids: the *acidity of the fluid must not be neutralised or the fluid must be rendered acid;* the temperature must be above 40° or 50° and below 120°. A *temperature of about* 100°, the *division & softness* of the nitrogenous substance, and its *frequent agitation* considerably assist the action.

The gastric juice *acts catalytically,* i.e., by mere presence; its action differs however from that of a ferment in its not being indefinitely continued, in its not requiring the presence of oxygen, and in its not causing the evolution of carbonic acid. – The change effected in albuminoids by the gastric juice consists, according to some, in their becoming combined with water; metamorphoses analogous to those effected in digestion may be produced by prolonged boiling in water.

DIGESTION in the STOMACH or GASTRIC DIGESTION.

From one to two hours after a meal the contents of the stomach are found transformed into chyme, which is a thick pultaceous, grumous substance of a strong disagreeable acid taste & odour, variable in colour according to the nature of the food taken, often coloured by the admixture of bile.

Chyme contains: –

1. The nitrogenous or albuminous principles of food partly dissolved, that is to say transformed into albuminose or peptone, partly reduced to a pulpy state only, and forming in that condition the greater portion of the chyme. – The gastric juice meets in the stomach with the conditions the most favourable to its action, a temperature of about 100 F., the state of division & softness, and the constant agitation of the substance upon which it has to act; to which favourable conditions may be added the repeated removal of those portions of food that have been acted upon, by which removal the remainder of the food is brought into closer contact with the solvent fluid. The transformation of the food into chyme & its dissolution take place therefore much more rapidly in natural digestion than in the artificial digestions as they are usually conducted.

2. Starch & amylaceous principles with a little dextrin & grape-sugar, the two latter being the result of the action of the saliva upon the former, which action begins in the mouth & is probably carried on also to some extent in the stomach. A small portion of the grape-sugar appears to be further transformed into lactic acid. It is only in the small intestine, however, that the mass of the amylaceous food is digested, that is to say rendered soluble in the form of grape-sugar, and made capable of being absorbed.

3. Oleaginous principles in a fluid condition & in a state of considerable division, but otherwise unchanged. The state of division of the oleaginous principles is due to their being set free gradually from the areolar & other tissues in which they are contained, by the solvent action of the gastric juice on the latter, and also, probably, to the mechanical action of the walls of the stomach upon its fluid contents.

4. Insoluble substances not capable of being digested. These are animal & vegetable. Some animal substances & structures, dense, hard and but slightly vascular, are acted upon very slowly, and, during the time of a normal digestion, but very imperfectly by the gastric juice; such are cartilage, fibro-cartilage, the white fibrous & yellow elastic fibrous tissues, the walls of the blood vessels, the skin & mucous membranes, etc. Such rather exceptional parts of food are not digested in the stomach, nor, usually, in the intestine either, and, being but slightly modified, pass out with the fœces.

The gastric juice has no special solvent action on the non-nitrogenous principles, which form so large a part of vegetable substances. These latter with the above mentioned insoluble or scarcely soluble animal substances, pass early from the stomach into the intestine. They are no longer found in any quantity in the stomach when the greater mass of the nitrogenous parts of the food are still contained therein, and are the first to make their appearance at an abnormal opening, such as an artificial anus. Some of the parts of vegetables, such as the walls of the sap-vessels, the spiral vessels, the cell membranes, and lignin generally, are equally insoluble, even in the small intestine, with the animal substances & structures above mentioned. This opens up a view of the digestibility of the various articles of food different from that taken by Dr. Beaumont.

Liquids & dissolved substances are immediately absorbed by the stomach & also by the intestine, into which they pass rapidly. Alcoholic drinks appear to give off a little acetic acid.

THE AGENTS of the INTESTINAL DIGESTION.

THE BILE - *Greatly assists the pancreatic juice in emulcifying the fatty portions of the food, and facilitate their absorption through the coats of the intestine*: – The ligature of the common bile duct immediately transforms the white milky contents of the intestinal lacteals after a meal into an almost transparent fluid containing but about ½ the normal quantity of fat globules. Animals soon die after the operation on account of the reabsorption or non-elimination of some of the principles of the bile. The more satisfactory operation of establishing a biliary fistula allows of a more prolonged experiment, the animal dying but slowly and from the consequences of insufficient nutrition only; a large proportion of fat is then continually found in the fœces. — Bile has *no action upon the albuminoids*, and has but a *very slight action upon the amylaceous principles*. — (Vide also Secretion of bile).

THE PANCREATIC JUICE — Is *clear colourless, alkaline*, viscid and chemically more active *about two hours after a meal*, more watery & less active later on. — The average quantity daily secreted in man is estimated at from 12 to 16 ozs. (Bidder).

It contains 980 parts of water, salts very similar to those found in the saliva (except that the sulpho-cyanide of potassium is deficient) and a peculiar nitrogenous substance termed *pancreatin*, to which however it is a mistake to attribute its digestive power (Foster).

It transforms starch into dextrin and subsequently into grape-sugar, as does the saliva.

It *shares with the bile*, but it possesses to a much greater degree than the latter, *the property of emulcifying fat*: – Fat appears in abundance in the fœces when the pancreas is diseased or when its duct is tied. In the rabbit the fatty matters, though subjected to the action of the bile which is poured into the intestine a little below the pylorus, remain nearly unchanged in the part of the intestine situated above the opening of the main pancreatic duct, (which latter opens 10 or 12 inches below the common bile-duct) and the corresponding lacteals contain but a thin watery fluid (Bernard).

It has probably *a slight action on the albuminoids*, especially when it co-operates with the gastric juice.

THE INTESTINAL FLUID — Is secreted by the tubular glands or glands of Lieberkühn and by the small conglomerate glands of Brünner.

It is colourless, viscid, alkaline, and contains water, salts, fatty matters, and an organic principle. The average quantity daily secreted in man is estimated at about 7 ozs. (Bidder & Schmidt).

It *transforms starch into dextrin and subsequently into grape sugar*, and *dissolves the albuminoids*: – A case is on record, in which the contents of the stomach were, by a fistulous opening, completely prevented from entering the small intestine; upon food being introduced directly into the lower part of the small intestine, its albumen was dissolved, and its starch was converted into sugar; the *fats* were, however, *but slightly or not at all emulcified* (Busch). – The fluid, doubtless abnormal, which collects in a loop of intestine tied at both ends, appears, however, to be nearly inactive.

INTESTINAL DIGESTION.

Its object is to emulcify the fats, and to complete the transformation of the amylaceous food into dextrin & grape-sugar, and the transformation of the albuminous food into albuminose or peptone.

This is effected by the joint action of the bile, pancreatic juice & intestinal fluid, and, in the upper part of the intestine, by the continued action of the saliva & gastric juice.

The oleaginous principles of the food leave the stomach in a fluid condition & in a state of considerable division, but otherwise unchanged. They are emulcified in the upper part of the small intestine by the joint action of the bile & pancreatic juice, and are thereby rendered capable of being absorbed.

The amylaceous principles of the food are acted upon to some extent by the saliva both before entering the stomach and during their stay therein. The great mass of the amylaceous food is however undigested when it enters the small intestine. It is here acted upon by the pancreatic juice & by the joint secretions of the glands of Brünner & Lieberkühn, and is transformed first into dextrin and then into grape-sugar, which latter is soluble & capable of being absorbed. – The great length of the small intestine in the herbivorous animals corresponds to the difficult digestion of vegetable substances, especially when they are uncooked.

The albuminoid principles of the food are especially acted upon in the stomach, which they leave only when they are reduced to a semi-fluid condition by the action of the gastric juice. Their transformation into albuminose or peptone is completed in the small intestine by the continued action of the intestinal fluid & pancreatic juice.

All these changes take place principally in the upper part of the small intestine. They are continued however in the lower part of the same, and even to some extent in the large intestine, for nutrient enemata are of service when no food can be taken into the stomach.

There is no reason however to believe that any special digestive process takes place in the cœcum or in any other part of the large intestine.

THE FUNCTIONS of the SPLEEN.

The spleen

I. - Is a seat of disintegration of the red blood corpuscles - For these are greatly diminished in number in the blood of the splenic vein, while they are found in abundance in the splenic pulp, where, according to Kölliker, they collect into heaps, and become surrounded by a cell-wall and more & more altered in form & colour till they are finally converted into pigment granules.

II. - Is a seat of formation of fibrin & of the white or lymph corpuscles, which latter are probably **the germs of the future red blood corpuscles** (Vide functions of the blood glands in general) - For the blood of the splenic vein contains an unusually large amount of white corpuscles, sometimes as many as 1 to every 60 red corpuscles (Hirt), and of fibrin, sometimes as much as 11 parts per 1000.

III. - Probably elaborates the albuminous or formative materials of the food - For it is much the largest towards the close of the digestive period, or about four or five hours after a meal, and its parenchyma then contains an unusually large amount of finely granular albuminous material & of young nucleated & non-nucleated cells & free nuclei. The Malpighian corpuscles are also largest & most numerous when the nutrition is active.

IV. - Is a diverticulum to the portal system.

N. It must be observed that all these functions may be performed by other organs, since the spleen has frequently been removed, even in man, without any serious effects resulting.

THE FUNCTIONS of the LIVER

Are twofold, depurative & assimilative.

Depurative Action – Frees the blood from foreign substances & from effete protein compounds ready to undergo retrograde metamorphoses. – A part of these compounds, *i.e.*, that part which contain the nitrogen & the sulphur, are, in the form of bile, made subservient to the digestive process before they are finally discharged.

Assimilative Action – Modifies the albuminose & the sugar conveyed to the liver from the alimentary canal, and also, probably, the remainder of the above mentioned protein compounds, and, after rendering them fit for nutrition, forms out of them oleaginous & amyloid materials, which are subsequently transformed into blood & tissues: – When either albuminose or cane sugar is injected into any vein but the portal vein it is immediately eliminated through the kidney; it is on the contrary assimilated when it is injected into the portal vein and thus subjected to the action of the liver.

THE SECRETION of BILE

Probably amounts daily in man to 2 or 3 pounds.

Though never entirely interrupted, the process is greatly *accelerated from one to two hours after a meal.* The bile is then poured out in abundance both from the liver & the gall-bladder, the latter contracting to expel the bile previously collected in it. The relatively small amount of bile secreted during the intervals of meals is pressed up the cystic duct into the gall-bladder on account of the closure of the orifice by which the ductus communis choledochus communicates with the duodenum, this orifice being forced open only when the gall-bladder contracts; the peristaltic action of the bile-ducts probably assists also in producing the retrograde movement of the bile.

Bile is a *heavy, viscid fluid* of a *greenish-yellow colour, very bitter, neutral or slightly alkaline,* and of a specific gravity of about 1020. When retained in the gall-bladder it becomes darker, more viscid & ropy, through increased concentration & the addition of mucus.

Bile contains *water, bilin, fats, colouring matters, mucus* & *salts* in the following proportion per 1000 parts of bile:

Water, 860.

Bilin, 90. – Bilin is a resinoid substance formed by the combination with soda of two resinous acids, the *glycocholic* & the *taurocholic,* the latter of which contains sulphur while the former does not. It is soluble in water, alcohol & alkaline solutions, and is the most important constituent of the bile.

Fats, 9: – Olein, margarin, cholesterin probably held in solution by the bilin; also alkaline oleates, stearates & margarates.

Colouring Matters: – *Biliverdin,* which is green; *bilifulvin,* which is yellow; both closely allied to hæmatin. On the addition of nitric acid they become dark green. With the mucus, from which they cannot well be separated, they form about 30 parts per 1000.

Mucus – Derived principally from the gall-bladder, but partly also from the hepatic ducts.

Salts, 7. – The most important are the chloride of sodium, the carbonate & phosphate of potash & soda, & the phosphate of magnesia. Bile contains also some iron, and frequently also a little copper.

The bile is *secreted mainly from the portal blood;* it therefore diminishes greatly in quantity when food is withheld, and ceases entirely to be formed when the vena portæ is tied. If, however, the constriction of the vena portæ is gradual, the secretion will continue to some extent through the then probably increased supply of blood from the hepatic artery.

The *bilin* & the *colouring matter* do not preexist in the blood; they *are formed* in the liver *during the act of secretion* of the bile, and are probably derived in part from the products of organic disintegration, and in part from the portion of the albuminoids which is simply assimilated into the blood and which does not undergo metamorphosis into tissue.

Irritation or division of the pneumogastric nerves below the diaphragm does not affect the biliary secretion. *Division* of one or both nerves *higher up interferes with* the secretion, probably in consequence of the effect produced on the circulation & respiration.

THE USES of BILE.

I. Greatly assists the pancreatic juice in emulcifying the fatty portions of the food, and facilitates their absorption through the coats of the intestine. – Vide Agents of the intestinal digestion.

II. Prevents the decomposition & putrefaction of the food during its passage through the intestine – After ligature of the bile-duct or the establishment of a biliary fistula the contents of the intestine become much more fœtid than they usually are.

III. Acts as a slight purgative, increasing both the quantity of the fluid secreted by, and the vigour of the peristaltic contractions of, the walls of the intestine. A scanty supply of bile produces constipation, an excess induces diarrhœa.

IV. Is an excrementitious fluid, by which the excess of carbon & hydrogen, not used up by the respiratory combustion, is separated from the blood. This is shown on the one hand, by the elementary composition of bile being so very rich in carbon & hydrogen & so deficient in nitrogen ($C_{76}H_{66}N_2O_{22}$, Liebig), and on the other hand, by the fact that the secretion is actively carried on both during intra-uterine life (when the liver is even remarkable for its size & vascularity) and during the winter slumber of the hibernating animals: – The meconium of the fœtus is but thickened bile admixed with mucus, and the fœces of the mole during winter are very little more.

The biliary excretion is therefore vicarious to the pulmonary. In the case of the adult this holds true particularly in hot climates, where the high external temperature renders necessary the combustion, for the maintenance of animal heat, of but a small quantity of carbon & hydrogen, and where, however abstemious a man may be, his liver is much more active, and also much more liable to be diseased, than in the temperate or cold regions of the globe. – It must however be remembered that in the adult a large proportion of the bile, which proportion comprises nearly the whole of the bilin, is reabsorbed in the intestine, the fats & the colouring matters being alone excreted with the fœces. The reabsorbed bilin is believed to be converted, by the respiratory combustion, into carbonic acid & water, its sulphur probably reappearing in the acids of the sulphates found in the urine. The elimination of carbon & hydrogen, through the bile, is therefore, in the adult, to some extent *indirect.*

THE AMYLOID SUBSTANCE — GLYCOGEN (Bernard), HEPATIN (Pavy), ZO-AMYLINE (Rouget).

Is formed in the hepatic cells, and may be extracted from the liver by breaking up the organ & macerating it in water, boiling the water in order to coagulate the albumen, filtering, and adding a little acetic acid or alcohol, either of which latter reagents will precipitate the substance sought for.

It is white, flocculent, tasteless, soluble in water, insoluble in alcohol; identical in chemical composition with starch, sugar & dextrin; and rapidly transformed, when an albuminoid ferment is added, first into grape sugar and then into alcohol or acetic acid. It forms a reddish violet compound with iodine, but does not reduce the salts of copper.

It is probably derived from the three following sources:—

1. *From the amylaceous principles of the food,* for it is found most abundantly in the liver when purely vegetable diet is taken.

2. *From the albuminoid principles,* for the blood of the portal vein is rich, and that of the hepatic veins relatively poor, in these principles (M'Donnell).

3. *From disintegrated protein compounds reabsorbed from the blood,* only a part of which, probably, are employed for the formation of the bile.

Its uses are still enveloped in obscurity.

The theory of its transformation into sugar (Vide History of the "Glycogenic Function") must now be rejected:—whatever be the nature of the food administered, the liver contains little or no sugar *during life.* There is also during life very little or no difference in the amount of sugar found in the blood of the portal & in that of the hepatic veins. It is only after death, that sugar is formed in the liver, unless abnormal conditions be induced by the exhibition of morphia, phosphoric acid or strychnia, or by the injection of chloroform or ammonia into the portal vein, the irritation of the floor of the 4th ventricle, the division of the sympathetic nerve in the neck, etc.

Dr. Pavy, to whom science is greatly indebted for dispelling an important physiological error, suggests that the amyloid substance represents a first step in the assimilation of the amylaceous principles of the food, that it stands, as a transitory product, in an intermediate position between these latter principles & the fats, and that it arises from the fat-forming process stopping short in the liver at an imperfectly evolved substance, the final evolution of which substance into fat is subsequently accomplished either in the liver or elsewhere.

THE HISTORY of the "GLYCOGENIC FUNCTION" of the LIVER

Is now but an interesting page of past physiological research, which reads in a few words as follows:—

"One of the functions of the liver is the formation of *sugar*, which being *taken up by the hepatic* "*veins* and being *easily oxidisable*, forms the material, the *subsequent combustion* of which "throughout the vascular system is the *principal source of animal heat*."

"Sugar is *not formed directly* in the liver. It is *preceded* by a substance very similar to, and "indeed identical in composition with starch, which substance is termed *glycogen* "(Bernard), *hepatin* (Pavy), *zo-amyline* (Rouget). This substance is immediately "transformed by the action of albuminoid ferments, first into grape-sugar, and then into "alcohol & lactic acid."

"This *transformation* of glycogen into sugar is *constantly taking place* in the liver *during life.* "It *continues even after death;* after washing out completely the vascular system of the "liver by injecting water into the portal vein until the fluid escaping from the hepatic "veins was perfectly colourless, and no longer contained a trace of srgar, Bernard again "found sugar in the fluid of subsequent injections performed at intervals during 24 hours. "The repeated washing of a portion of liver tissue proves also the same continued forma- "tion of sugar after death."

"The *precise origin* & *mode of formation of glycogen* & *sugar* is still uncertain. Though sugar "is much more abundant in the hepatic veins, and in the circulatory system generally, "after a meal, especially if a considerable quantity of sugar or amylaceous substances "has been taken, and though much more sugar is obtainable from the liver of herbivorous "than from that of carnivorous animals (4 per cent. from that of a calf, 2 per cent. from "that of a dog), it can*not* now be objected, as it originally was by Sanson & others, that "the sugar found in the blood is *derived from the food*, for sugar is still formed in the "liver, and is even found in the blood in nearly the usual proportion in the case of starving "animals or of animals fed wholly upon meat or fat; after a meal the blood in the jugular "vein of a horse contains .06 per cent. of sugar and that in the hepatic veins 1.13 (Poiseuil- "le & Lefort); when the animal has been fasting for a week the respective proportions "are .05 (Chauveau) & 1 per cent. (Marshall)."

"The glycogenic function of the liver is therefore to a certain extent independent of the ab- "sorbed products of the alimentation. It is *probable* however that the materials with "which the liver forms sugar are *principally derived from the albuminoid principles of the* "*food*, for it has been shown that the formation of sugar diminishes & that the tempera- "ture falls in animals fed wholly on oil or chemically pure starch, while both are normal "in animals fed on albuminous diet only. (Bernard, Schmidt, Savory)."

"The *glycogenic function* is *governed* by the *joint action of the pneumogastric nerves, acting as* "*centripetal nerves from the lungs to the nerve-centres, and of the vaso-motor branches of* "*the sympathetic* which supply the vessels of the liver. It is probably *regulated accord-* "*ing to the quantity of oxidisable substance required for the maintenance of animal heat* "& is thus rendered subservient to the respiratory functions. The section of the pneumo- "gastric nerves above their pulmonary branches restrains the formation of sugar, while the "formation of sugar is greatly increased by the irritation of the roots of the same nerve "on the floor of the 4th ventricle (Bernard), or of the upper part of the medulla oblongata, "and also by the section of the great splanchnic nerves or of the sympathetic in the neck, "a temporary diabetes immediately resulting. It is probable that the increased formation "of sugar depends on the *temporarily increased vascularity of the liver* for the direct "stimulation of the liver by acupuncture needles (Schiff) or by irritating injections "(Harley) produces the same effect."

NEW POINTS in DIGESTION.

Active Principles, or Ferments,* of the Saliva and Gastric & Pancreatic Juices.

These were believed up till very lately to be *nitrogenous substances;* it is now more than likely that they are *not:* – If a salivary gland, or a portion of the gastric mucous membrane, or of the pancreas, be left standing under alcohol for some time, the proteids they contain will become coagulated and insoluble either in water or glycerine. Nevertheless either an aqueous or a glycerine extract, though it contain little or no proteid material, will be found to be actively amylolytic or peptic, or both, as the case may be. The more elaborate method of Brücke supplies a digestive fluid, which presents none of the ordinary proteid reactions, but which, nevertheless, is exceedingly active.

These ferments exist in the several fluids in extremely small quantities. They probably act catalytically, *i.e.*, by mere presence: there is no evidence that they are subject to any change during the chemical action to which they give rise. It is probable, therefore, that the loss of power which they may sustain is due to simple wear & tear. Boiling destroys their activity, as does also the action of strong acids, or strong alkalis.

*The term "ferment," though sanctioned by modern usage, is here somewhat misapplied: — These active principles are not living organisms, like yeast; they are not gendered by an organic predecessor in the shape of a germ. Neither is the presence of oxygen a necessary condition for their action, nor is carbonic acid a product thereof. They are mere secretions, whose action is chemical, not vital.

Chemical Constitution of the Starch-Corpuscle.

The enveloping membrane of a starch-corpuscle consists of *cellulose,* which is acted upon with great difficulty by the digestive fluids; this substance gives no blue colour with iodine, unless sulphuric acid be added. The interior of the globule consists of *granulose,* which is much more easily acted upon, and which immediately gives a blue colour with iodine alone. – When starch is boiled, the membrane of cellulose is ruptured; the saliva has then a ready access to the granulose: starch paste is digested much more rapidly than raw starch.

Erythrogranulose.

Combined with the granulose of the interior of the starch globule, Brücke distinguishes a little *erythrogranulose,* which gives a red colour, not a blue colour, with iodine, and is less rapidly acted upon by saliva.

Erythrodextrin, and Achroodextrin.

Brücke also divides dextrin into *erythrodextrin & achroodextrin.* Erythrodextrin is the product usually described under the name of dextrin: it is easily acted upon by saliva, and it gives a red colour with iodine. Achroodextrin exists in small quantities only; it gives a yellowish colour with iodine, and is acted upon with difficulty by saliva. An amylaceous fluid which has been acted upon by saliva till it no longer gives either a blue or a red colour with iodine, may still contain a certain amount of dextrin in the shape of *acroodextrin.*

Action of Dilute Acids upon Starch.

Dilute acids transform starch into *soluble starch* or *amidulin,* which, like dextrin, forms a clear solution with water; but still gives a blue colour with iodine. It is suggested that, in the stomach, the gastric juice might transform some of the starch into amidulin. The amidulin would subsequently be transformed into dextrin & grape-sugar in the intestinal canal, as is ordinary starch.

Action of Saliva upon Starch.

Another account of the action of saliva upon starch is that it first splits up the starch into sugar and dextrin, and then transforms the dextrin into sugar. The change consists essentially in the assumption of a molecule of water.

The action is favoured by a temperature 100° F., or 40° C., by the alkaline reaction of the medium, by the progressive removal of the sugar formed. It is hampered by high & by low temperatures, by an acid medium, by the accumulation of the sugar.

The degree of chemical activity of the saliva, and the relative activity of the several kinds of saliva, vary greatly in different animals. In man the submaxillary saliva is more active than the parotid saliva. – With fats, saliva produces a feeble emulsion.

Note – When mixed with mucus, gastric juice transforms cane-sugar into grape-sugar. Cane-sugar, when in excess, causes an abundant secretion of mucus, and thus provides for its own digestion.

The Free Acid of the Gastric Juice.

Is now definitely proved to be hydrochloric acid, for the amount of hydrochloric acid in gastric juice is shown to be greater than can be neutralised by the bases present. The proportion of free hydrochloric acid is ·02 per cent. Lactic, butyric, and other acids, when present, are the result, either of fermentation, or of the decomposition of their alkaline salts by the free hydrochloric acid.

The activity of an artificial peptic digestive fluid is brought up to its maximum by such fluid being acidified with ·02 per cent. of hydrochloric acid. Other acids are less efficient as regards digestion.

There is an intimate connection between the acid & the ferment. They act together as one compound, to which, indeed, the name *pepto-hydrochloric* has been given.

Parallel between the Action of Dilute Acids & that of Gastric Juice upon the Albuminoids.

1. Dilute acids transform the albuminoids into acid-albumin or syntonin, which, though easily dissolved in slightly acid fluids, is thrown down at any time upon neutralisation. Gastric juice transforms the albuminoids into peptone, which is not thrown down upon neutralisation.
2. Neither solution is coagulable by heat.

Further Remarks upon the above mentioned Solutions.

It must be remembered that it is only by a slow process that albumin is transformed either into acid-albumin, or into peptone, as the case may be. Therefore, if raw white of egg, *i.e.*, uncoagulated albumin which is soluble in water, be used in the experiment, and if the solutions be tested too soon, they will both be found to be partly coagulable by heat, & partly precipitable upon neutralisation: – *The acid solution* will be partly coagulable by heat, because it will still contain some native albumin not yet transformed into acid-albumin; it will be partly precipitable upon neutralisation because it will already contain *some* acid-albumin. *The peptic solution* will be partly coagulable by heat because it will still contain some native albumin not yet transformed into peptone; it will be partly precipitable upon neutralisation because it will contain, in addition both to the native albumin, and to the peptone that has been formed, a portion of the albuminoid, which, on the one hand, is no longer in the condition of the primitive native albumin, but, on the other hand, is not yet in the condition of peptone. This initial or intermediate product is referred to below as *parapeptone* & its several varieties.

Further Remarks upon the Neutralisation Precipitates.

As regards the precipitate thrown down, it will, in the case of the acid solution, represent the whole of the albumin that was dissolved; in the case of the peptic solution, it will represent, on the contrary, but a portion of the albumin dissolved; – and this portion will be relatively large in the early stages of the reaction, and relatively small in the later stages.

Further, the precipitate obtained from the acid solution is always the same at whatever time it is thrown down; it is always the well defined product termed acid-albumin. From the peptic solution, on the contrary, slightly different precipitates are thrown down, according to the time at which the precipitation is effected. These precipitates are the somewhat ill-defined products termed para-, meta-, & dyspeptones.

Note – If the peptic digestive fluid be sufficiently active, and the process of digestion be sufficiently prolonged, the whole of the proteids may be converted into peptone; in such case there will be no neutralisation precipitate.

Digestive Proteïd Metabolism, or Proteolysis. - Views of Brücke, Meissner, & Kühne.

Brücke held that, in gastric or peptic digestion, the albuminoids are first transformed into syntonin or parapeptone, and that this syntonin or parapeptone is subsequently converted into peptone.

Meissner held that the syntonin becomes split up into peptone & "parapeptone," – this "parapeptone" being characterised by the double fact of its incapability of being transformed into peptone by the continued action of gastric juice, and of its capability of being so transformed by the action of pancreatic juice, and being therefore, to all appearances, identical with the anti-albuminate of Kühne mentioned below. Of peptones, Meissner recognised three varieties, the *a, b, & c* peptones, the latter being the final or perfectly evolved peptone. He further recognised two subsidiary products, *metapeptone & dyspeptone.*

Kühne held that the albuminoids are split up both in gastric or peptic digestion, and in pancreatic, or, as he called it, in *tryptic* digestion, into two parallel series of products, the *anti* & the *hemi* series. From the initial products to the final products, these series contain:

1. *Antialbuminose, & Hemialbuminose,* which are subsequently transformed respectively into
2. *Antipeptone, & Hemipeptone.*

In peptic digestion, antipeptone & hemipeptone are the two final products; they are both peptones in the ordinary sense of the term. In tryptic digestion, on the contrary, though antipeptone is still the final product of the *anti* series, hemipeptone is no longer the final product of the *hemi* series: it is subsequently transformed into leucin, tyrosin, fatty acids, & volatile bodies, *i.e.*, into the various products of pancreatic digestion, among which is *indol.*

Respective Shares of Action, in Peptic Digestion, of the Hydrochloric Acid, & of the Pepsin.

Are stated by Kühne to be as follows, namely, that though the acid alone can evolve the two products of the *hemi* series, the cooperation of both digestive agents is necessary to effect the perfect evolution of the products by the *anti* series: – Acting on albuminoids at 40° C., dilute hydrochloric acid gives rise to hemialbuminose & hemipeptone, and to *antialbuminate;* which latter is transformed into antipeptone by trypsin only, not by pepsin, and is thefore apparently identical with the "parapeptone" of Meissner. This antialbuminate is formed in greater or less abundandance in all peptic digestive fluids poor in pepsin.

*Note - It will be observed that the term "*Syntonin*" has been used in two different senses, – as synonimous with parapeptone & its several varieties, and as synonimous with acid-albumin. This slight misuse of language is sanctioned by usage, and adopted for convenience' sake. It is partly justified by the fact that the three substances, though of different origin, and possibly of different constitution, are *chemically* undistinguishable, or scarcely distinguishable, one from the other.

The Active Principles of Pancreatic Juice

Are probably three in number: – one acts upon the starch; a second acts upon the proteids; a third emulcifies the fats.

The emulcifying power appears to be due, in part at least, to a special form of alkali-albumin, which is closely associated with sodium carbonate, and is precipitable on saturation of the juice with magnesium sulphate. This agent emulcifies neutral fats, and splits them up into their respective acids & glycerine; – the mixture soon takes on an acid reaction. When an alkali is present, the fatty acids are set free, and form their respective soaps.

Variations in the Composition of Pancreatic Juice.

Independently of the variations already mentioned in the proportion of solid constituents taken as a whole, there are other important variations due to *intrinsic digestion* of the comparatively large proportion of *proteids & fats* always found in pancreatic juice. To this process must be attributed the *peptone* & the *soaps*, which are usually present, the *leucin, tyrosin*, etc., and possibly also the *indol.* There is also a considerable proportion of *sodium carbonate*, which salt seems to be very closely associated with the peculiar form of *alkali-albumin* above mentioned.

When left to cool, pancreatic juice undergoes a sort of coagulation; but it again becomes fluid, when gently heated. According to Kühne, this coagulation would be a true coagulation due to the formation of a product similar to *myosin*; and the subsequent liquefaction would be due to intrinsic digestion of the clot.

Tryptic or Pancreatic Digestion of the Albuminoids Compared with the Peptic or Gastric.

1. – Peptic or gastric digestion is essentially an acid digestion: the action takes place only in the presence of an acid, and is arrested on neutralisation. Tryptic or pancreatic digestion is essentially an alkaline digestion: the action will not take place unless some alkali be present; it is hindered by neutralisation, and arrested by acidification. – The presence of 1 per cent. of sodium carbonate induces the maximum of activity in an artificial tryptic digestive fluid. One per cent. of sodium carbonate seems, in fact, to play, in pancreatic digestion, a part altogether comparable to that of ·02 per cent. of hydrochloric acid in gastric digestion (M. Foster). Bile, which arrests peptic digestion, seems, if anything, to favour pancreatic digestion.

2. – The initial product of peptic digestion is acid-albumin or syntonin. The initial product of tryptic digestion somewhat resembles alkali-albumin or casein: It is soluble, not only in dilute acids & dilute alkalis, but also in a 10 per cent. solution of sodium chloride; and the solutions in the latter reagent coagulate on boiling and on the addition of strong nitric acid.

3. – In peptic digestion, the whole of the proteid, or nearly so, is transformed into peptone. In tryptic digestion, on the contrary, a considerable portion is broken up into leucin, tyrosin, fatty acids, & volatile substances, among which latter, as above stated, is possibly *indol*, which compound it is that gives their strong & peculiarly fœcal odour to the products of tryptic digestion. This indol is believed, however, by some to be a product of decomposition.

4. – Fibrin undergoing peptic digestion, swells up, becomes semi-transparent, and then falls to pieces, leaving a little granular débris. When undergoing tryptic digestion, it remains opaque, diminishes slowly in bulk by a kind of superficial corrosion, and leaves no débris, or very little.

Note – While gastric juice dissolves gelatiniferous tissues, and destroys their characteristic property, the property of gelatinisation, pancreatic juice, on the contrary, has no action upon them.

Bile-Pigments.

Human bile, and the bile of carnivorous animals, are normally of a bright golden red colour; that of herbivorous animals is of a golden, bright, or dirty green, according to the time of retention in the gall-bladder.

The pigment of human or carnivorous bile is *bilirubin*. Bilirubin is readily soluble in chloroform & alkaline fluids, slightly soluble in alcohol & ether, insoluble in water. When treated by oxidising agents, such as nitric acid *yellow with nitrous acid*, it turns in succession green, greenish blue, blue, violet, dirty red, pale yellow (Gmelin's test for bile-pigments). When treated by alkalis and exposed to the air in a shallow vessel, it becomes converted into *biliverdin*, which is the green pigment of herbivorous bile, and probably also, of biliary vomits. Biliverdin constitutes the first stage of oxidation of bilirubin in Gmelin's test. When obtained pure from herbivorous bile and subjected to the action of oxidising agents, it goes through the samo series of colours as bilirubin, the initial golden red excepted. When subjected to the action of reducing agents, it becomes converted into *urobilin*, which is sometimes found in the urine of fever patients. Other pigments, such as *bilifuscin*, *biliprasin*, etc., have also been described as occasionally present in gall-stones.

Bile Salts, or Bilin.

In human bile, the sodium taurocholate is much more abundant than the sodium glycocholate; and in the bile of the carnivora, it exists alone. In the bile of herbivorous animals, there is, on the contrary, a large excess of sodium glycocholate. Both these salts crystallise in fine acicular needles.

Their acids may be isolated by means of sulphuric acid. When boiled with dilute acid, caustic potash, or baryta water, these acids break up, as they also do spontaneously in the intestine, the glycocholic acid, into cholalic acid & glycocoll, and the taurocholic acid, into cholalic acid & taurin. When treated with sulphuric acid & cane sugar, they give a splendid purple colour (Pettenkofer's test), and a characteristic spectrum.

Action of the Bile on Food.

It precipitates the products of gastric digestion, throwing down mainly the parapeptone & the greater part of the pepsin; so that the supernatent fluid, even when reacidified, has but little or no peptic power. It is said by some that the peptones are thrown down also. A solution of bile salts has the same action.

With the free fatty acids, the bilin forms soaps.

Intestinal Fluid

Is probably secreted to a certain extent by the epithelial cells of the mucous membrane itself (M. Foster). This is in keeping with the view of the process of secretion now generally received (V. Secretion in General, page 56). – Almost every statement made in respect of the action of the intestinal fluid has been contradicted by some physiologist or other.

The Digestion of Milk.

Milk is first coagulated or curdled by gastric juice, that is to say, its casein is precipitated; and the casein is then digested as any other solid proteid. The agent of this coagulation is not the acid of the gastric juice, for neutralised gastric juice will still curdle milk; neither is it the pepsin, for the purest pepsin obtainable, Brücke's pepsin, has no coagulating power. It is probably a special ferment (M. Foster).

Mechanisms which Govern the Secretion of the Digestive Juices.

In the case of the submaxillary gland, the secretion is brought about by the advent along the chorda tympani of efferent impulses started by reflex action. These impulses travel along two sets of fibres, the *vaso-dilator* & the *excito-secretory*, the former fibres probably acting through some local vaso-motor centre. Both the submaxillary ganglion and the cervical sympathetic have probably also a regulating influence; but this influence is not yet well understood. – For further details, see pages 36 & 110, and Appendix, page 12[D]).

The other secretions are probably governed by similar reflex mechanisms, but very little is yet known on the subject.

In connection with the above, a separate consideration is given in the two following pages to the *Intimate Phenomena of the Act of Secretion*

INTIMATE PHENOMENA of the ACT of SECRETION.— ZYMOGEN,* TRYPSINOGEN.

Secretion is a complex & active process consisting of: –

1. – *The Production of Zymogen;*
2. – *The Stowage of the same;*
3. – *The Transformation of the Zymogen into the specific ferment during the outflow or [excretion.*

The formation & stowage of the zymogen form part of the nutrition & growth of the cell; they constitute a slow & continuous process.

The transformation of the zymogen into the specific ferment is a rapid & intermittent process, specially called forth in every instance by an efferent nervous impulse.

This was established as regards the pancreas by Heidenhain's observations on that gland, and has since been confirmed by various observations on the gastric & salivary glands: –

The cells of the pancreas present two zones, an *outer zone,* homogeneous or slightly striated, which stains easily with carmine; & an *inner zone,* finely granular, which stains with difficulty. The position of the nucleus varies, but it always lies partly within the inner zone, & partly within the outer one.

The outer zone is being constantly, but slowly, built up, on the one hand, with the materials absorbed from the blood; on the other hand, its accumulated materials are being constantly, but slowly, removed for the building up of the inner zone.

The inner zone, on the one hand, is being constantly but slowly built up at the expense of the outer zone; on the other hand, during the period of glandular activity, its materials are removed *rapidly and in large quantities* for the formation of the ferment to be excreted.

During repose, both zones increase in size, the inner one becoming, however, the larger of the two; and the nucleus is pushed outwards towards the basement membrane.

During activity, both zones diminish, the inner one becoming the smaller of the two; and the nucleus is drawn inwards towards the lumen.

It must be added, however, that the period of greatest activity of the relatively slow & continuous nutritive process coincides with the period of greatest activity of the relatively rapid & intermittent excretory process: this is the inevitable result of the afflux of blood towards the gland, which occurs during the period of excretion. Hence the time when the *inner zone* is the *largest* occurs *shortly after the close of the digestive period.* From this time to the commencement of the next digestive period, the size of the inner zone *diminishes slightly.*

The amount of ready formed proteolytic ferment present in the gland at any given time is *never very great:* – There is scarcely any during the intervals of meals; neither is there much even during the height of digestion: – If the pancreas be minced and treated with glycerine *while still warm from the body,* the extract will be all but inactive if the organ was removed a long time after a meal; and but slightly active, even if it was removed during the height of digestion.

The amount of zymogen, or rather *trypsinogen,* present *may,* on the contrary, *be considerable.* This amount is proportionate at any time to the size of the inner zone; and, as, after death, the trypsinogen is spontaneously transformed into the ferment (especially if a little dilute acetic acid be added), the amount of ferment, or of active glycerine extract, that can be obtained at any given time from the gland, rises and sinks *pari passu* with the size of the inner zone: – To obtain an actively proteolytic extract of the pancreas, the animal must be *killed* towards the close of the digestive period. It is true, as above stated, that, if the extract is made while the gland is still warm from the body, such extract will still be but slightly active (though, if diluted, it would subsequently become more active through spontaneous evolution of the ferment); but if twenty-four hours be allowed to elapse before the extract is made, or if the gland be first rubbed up in a mortar with a little dilute acetic acid, the extract will be as active as any that can be obtained.

* **Note** – The term "*zymogen*" will be used as a generic name for "mother of ferment," as suggested by Dr. M. Foster; and the several special products will be called *trypsinogen, pepsinogen,* etc.

CONFIRMATIVE OBSERVATIONS on the GASTRIC & SALIVARY GLANDS.

Gastric Glands. - Pepsinogen.

We must now cease to lay stress on the former division of these glands into *peptic* (or cardiac) & *mucous* (or pyloric), and discard the special application of the term "*peptic*" to those large ovoid granular cells which line the middle part of the cardiac glands; and this for the following reasons: -

(1). - Peptic zymogen, or *pepsinogen*, is formed alike in all these glands, in certain proportions at least: - An acid infusion of the pyloric end of the stomach, though at first without any action on albuminoids, soon becomes peptic.

(2). - Of the two kinds of cells which line these glands, those smaller & more regularly cuboid cells, which line the deeper or more central part of the cardiac glands and also the pyloric glands throughout, and which have hitherto been called simply the "*central cells*" & considered to be unimportant, are really the more important & properly peptic: - During digestion they become loaded with granular deeply staining proteid material, - doubtless pepsinogen, due to the transformation of the cell-protoplasm. In starving animals, on the contrary, they are pale, shrunken, less granular, and less capable of being stained with carmine.

During digestion, the lumen of the pyloric glands also becomes filled with similar granular material: This material is not digested food about to be absorbed, as was once believed; for it also makes its appearance after mechanical irritation of the mucous membrane of the empty stomach.

Salivary Glands. - Ptyalogen.

The submaxillary gland, when at rest, presents two kinds of cells: - The cells near the lumen of the tubes are regular in shape, transparent or slightly striated, and not easily stained with carmine; those near the basement membrane are smaller, flattened or half-moon shaped, and more easily stained. After the gland has been stimulated for some time through the chorda tympani, the half-moon cells have disappeared, and the cells near the lumen are distended with granular material, more readily stained, and less distinct in outline: The granular material of the half-moon cells has passed into the more superficial cells, or, possibly, the superficial cells have been shed, and the half-moon cells have taken their places.

Note. - It must be remembered that the amylolytic ferment is absent from the saliva of many animals, and that a doubt is thrown therefore upon the relations which the above changes bear to the production of this ferment: The term "ptyalogen" may possibly be misapplied.

ABSORPTION, etc.

Modern Views on the Mode of Entrance of the Chyle into the Lacteals.

I. – The lymphatic spaces or "saftcanälchen" of the retiform, lymphoid, or adenoid tissue of the villus (Recklinghausen) are in direct continuity with the central lacteal, which latter opens, on the other hand, into the submucous lymphatic plexus, from which the larger lymphatics arise. The only point to be explained is therefore the entrance of the chyle into the lymphatic spaces or saftcanälchen of the retiform tissue. – This is the view taken by Dr. Michael Foster.

II. – The lacteal has a complete wall of its own formed of flattened cells united by a small amount of intercellular substance, and therefore is not in direct continuity with the superficial lymphatic spaces, or saftcanälchen. Two points, therefore, require explanation, namely, (1) the entrance of the chyle into the superficial lymphatic spaces or saftcanälchen, and (2) the passage of the chyle from saftcanälchen into the lacteal proper. – This is the view taken by Prof. Shäfer.

III. – The latter view is completed by the following, also based upon Prof. Shäfer's observations : – The fat-globules of the chyle first penetrate into those amœboid lymph-corpuscles which pass up between the columnar epithelium cells on the surface of the villus, and are then carried into the lacteals by these amœboid lymph-corpuscles, just as minute solid bodies are carried by white blood-corpuscles out of the blood-vessels into the lymphatics.

III. – The penetration of the fat-globules into the lacteals is aided by the peristaltic movements of the intestine, and by the suction-pump action of the longitudinal muscular fibres of the villi, which action occurs whenever these fibres relax after contracting.

IV. – With reference to the penetration of the fat-globules into the epithelial cells of the villus, believed in by Dr. M. Foster and by most physiologists, and to their passage through these cells into the lymphoid tissue, Prof. Shäfer remarks that, at a later stage of digestion, fat-globules are found in the epithelial cells of the gall-bladder & bile ducts, into which they cannot have penetrated by absorption, and in which, therefore, they must have been formed *de novo*.

The apertures once believed to exist on the free surface of the epithelial cells are now shown not to exist. The circumstance which led to the belief in these apertures is the presence, on the free surface of the cells, of a layer of highly refracting substance marked with vertical striæ.

Vomiting.

Four acts or stages may be recognised : –

I. – *Air is introduced into the stomach*
  A. – By a copious flow of saliva, which saliva is swallowed;
  B. – By Retching.

Retching consists in deep inspiratory efforts, during which the glottis is closed. By this means air is drawn into the pharynx, whence it is swallowed.

II. – *The cardia is suddenly dilated* by the action of the longitudinal fibres of the œsophagus & radiating fibres of the stomach : – This can be felt to be the case if the finger be introduced into the stomach through a fistula. Vomiting becomes very difficult if the above mentioned fibres be divided or crushed by means of a tight ligature applied for a few seconds (Schiff).

III. – *The diaphragm being supported by the air retained in the thorax through the closure of the glottis* (and also somewhat depressed by a previous inspiration), *the abdominal muscles contract violently*, and compress the stomach against the diaphragm. The muscular walls of the stomach contract at the same time.

IV. – *The neck is stretched, the mouth is widely opened, the posterior pillars of the fauces are approximated.* The escape of a little air from the air-passages further protects them against the intrusion of the vomit.

These combined movements may be supposed to be governed by a "*vomiting centre*," closely associated with the respiratory centre.

ABSORPTION.

P.

LYMPHATICS & LACTEALS.

Their peripheral origins have not yet been clearly made out. It is probable, however, that they arise as follows, *i.e.*: – *beneath the skin and mucous & serous membranes,* in closely meshed networks; – *in the substance of the organs,* in irregular lacunar spaces or chinks comprised between the constituent elements of the organs, but probably lined, nevertheless, with a layer of squamous epithelium; – *in the centre of the villi,* in blind dilated extremities. A good deal has, however, been said lately (Heidenhain, Brücke, Funke, and others), about a direct communication being established between the cavity of the villi & that of the intestine through apertures on the free extremity of the epithelial cells which cover the villi and through a system of connective tissue corpuscles which join, by means of their caudate prolongations, the cavity of the epithelial cells to that of the central lacteal.

They present three coats: –

- External Coat – Formed of white & yellow elastic fibrous tissues longitudinally or obliquely disposed;
- Middle Coat – Formed of muscular fibres and white & yellow elastic fibrous tissues circularly disposed;
- Inner Coat – Consisting of an elastic layer longitudinally disposed and of a layer of squamous epithelium. – The two inner coats form the valves, which are usually placed in pairs.

The lymphatic glands present, according to His, Teichmann, Frey, & others, the following parts for examination, *viz*: –

- Fibrous Capsule – Which is continuous with the coats of the afferent & efferent vessels, and which sends lamellæ into the cortical portion of the gland; these lamellæ bound alveolar spaces communicating freely with each other and continuous both with the afferent & the efferent vessels.
- Medullary Substance – Consists of a reticulum of connective tissue fibres in the interstices of which are numerous lymph-corpuscles. This medullary substance occupies the centre of the gland, and sends out irregular prolongations into the alveoli, which prolongations nearly fill up, but do not completely fill up, these alveoli. Between them & the parietes of the alveoli are comprised a series of irregular spaces forming the
- Superficial Lymph-path of Frey – This latter is continuous both with the afferent & the efferent vessels; it is traversed by a few nucleated cells with anastomosing prolongations, and contains a few lymph-corpuscles. It is through this superficial lymph path that the lymph or chyle usually circulates. During the height of digestion, however, and when the nutrition is particularly active, a considerable portion of the fluid percolates through the interstices between the connective tissue fibres of the medullary substance, which latter interstices constitute the
- Deep Lymph-path of Frey – In which deep lymph path the lymph or chyle comes into intimate contact with the lymph-corpuscles & with the vessels, both of which are most abundant in this part of the gland.

LYMPH & CHYLE.

In the smallest lymphatics the lymph is a *transparent, colourless albuminous fluid, slightly alkaline, not spontaneously coagulable, but coagulable by heat. Chyle* is very similar to it in the smallest lacteals, its main peculiarities being that it contains *half as much again of albumen*, a *large proportion of oil globules* and also a multitude of minute fatty particles forming what is called its *molecular base* (Gulliver) and to which its opacity is due.

As the lymph and chyle pass through the lymphatic glands, *lymph and chyle corpuscles & fibrin* are formed in them, and they become spontaneously coagulable. – The farther they advance the more white corpuscles & the more fibrin they contain, and, in the case of the chyle, the fewer fatty globules. The two fluids then become very similar to each other, and also *very similar to the blood,* especially in the thoracic duct, where the lymph takes a pinkish tinge through the transformation of a few lymph corpuscles into red blood corpuscles. When the fluid from the lymphatic system is poured into the veins, it is therefore rudimental blood, containing, however, but $\frac{1}{3}$ or $\frac{1}{4}$ as much solid matter. – The quantity of mingled lymph & chyle poured into the veins is estimated in man at *about* 30 *lbs. daily.*

The evolution of the lymph & chyle corpuscles is a point of some interest. They are at first *mere nuclei,* and are not acted upon by acetic acid. As they progress they enlarge and acquire an albuminous coating, which coating is progressively transformed into a distinct *cell-wall.* They are then opaque & granular, and their nucleus is out of sight; but acetic acid brings the nucleus into view by rendering the mass of the cell transparent. It is probable that these corpuscles are *finally transformed into the red corpuscles of the blood.*

The progression of the fluid in the lymphatics & lacteals is due both to a *vis a tergo* and to a *vis a fronte.* The *vis a tergo* results from the conjoined action of the valves and of the muscular fibres of the middle coat, the action of the latter being aided by occasional pressure from without. The muscular fibres of the villi also constitute minute force-pumps probably stimulated into action by the irritating properties of the bile (Schiff). The *vis a fronte* results from the movement of the blood in the subclavian veins and also from the aspiration or suction induced by the respiratory movements. The *pressure in the large lymphatics* of the neck is equal to the weight of a column of water *from* $\frac{1}{2}$ *inch to* $1\frac{1}{2}$ *inches in height* (Noll), and the *rapidity of the current* in the same vessels is *about* 1·6*th of an inch per second* (Weiss).

ABSORPTION

Is on the one hand the function by which *fresh materials from the food & the air* are *introduced into the blood* & subsequently taken up by the tissues, and on the other hand the function by which the *products of organic disintegration* are *taken up into the blood* to be subsequently re-elaborated or excreted.

It is *far from being a purely vital process*: – If a portion of a vascular tissue be completely removed from the body and placed in water after its vessels have been tied, water will pass into these vessels, while the colouring matter, the albumen, & the salts of the blood will pass out into the water. Also if venous blood, in a moist bladder, be suspended in the air, the surface of the blood will become reddened by the absorption of oxygen from the air, and carbonic acid & watery vapour will pass out into the surrounding atmosphere.

Absorption is governed by the laws of osmosis applicable to the human body: –

As a general rule a substance to be absorbed must either be *in a fluid or gaseous state*, or must, if in a solid state, be *soluble* in the fluids of the parts with which it comes in contact. – Insoluble substances in a state of minute division such as particles of finely divided charcoal may pass, however, either into the veins or into the lacteals; into the latter, perhaps, through the apertures recently described by Heidenhain & Brücke.

The *less dense the fluid* to be absorbed and the *thinner the layer of tissues* that lie between it & the fluid in the vessels, the more quickly absorption takes place: – Water is absorbed more rapidly than saline solutions, and is absorbed more rapidly through the mucous membrane of the stomach than through the skin.

Diminished internal pressure increases, and *increased internal pressure diminishes*, *the rate of absorption*. Bleeding & fasting accelerate, a good meal or the injection of water into the veins retards, the action of poisons.

All other conditions being the same, *absorption into* the fluids circulating in the *vessels of the body* is much *more rapid* than is the osmotic current in an ordinary osmometer, for the fluid in the vessels, being constantly renewed, is maintained at a low degree of saturation & density.

ABSORPTION from the INTESTINE.

There is considerable *difference in the case of the intestinal canal, between the absorption by the veins and that by the lacteals.* Here, as elsewhere, the *veins absorb indiscriminately* all that comes in contact with them. The *lacteals,* on the contrary, would *appear to exercise a kind of choice* over the substances they admit into their interior: – Odorous & saline matters injected into the intestine are found early in the vena portæ, much later in the thoracic duct; if strychnia be used, poisoning will take place in a few minutes if the veins be not interfered with, in about an hour only, if they be tied. On the other hand, the fatty matters of the chyle are absorbed in abundance by the lacteals, while they are scarcely taken up by the veins. In the Author's opinion there is, however, no such thing as selection or choice on the part of the *lacteals.* These vessels, he believes, *absorb quite as indiscriminately as do the veins;* they even absorb with greater ease than do the veins on account of a nearly complete absence of internal pressure. Do they not take up the fatty matters, which the veins do not take up or scarcely take up? It is the *conveyance of the absorbed fluids towards the large trunks,* where alone they can well be sought for, and, in the case of poisons, it is their *conveyance towards the central organs,* upon which alone they act, that is *retarded* by the ligature of the veins, and the delay is due to the slowness of the circulation in the lymphatic & lacteal vessels.

STARVATION.

SYMPTOMS.

Objective & subjective; the former to be *observed* in animals only, the latter to be *subsequently ascertained* from man only. By co-ordinating both groups of symptoms, the following Tableau may be sketched:

For first day or two :–
- Wild & ravenous craving for food; eyes bright & staring;
- Violent epigastric pain, relieved by pressure;

Then follow :–
- Intense thirst, and sinking at pit of stomach.
- Secretions fail: urine scanty & strongly acid, mouth dry and parched.
- Fæces reduced in quantity, and, after first day, consist almost entirely of biliary matter.
- Circulation & respiration slacken, and temperature falls gradually.
- Tissues waste: eyes and cheeks sink, the more prominent bones project.
- Extreme debility & prostration; indifference to impending fate.
- Diarrhæa; body covered with a dirty brownish secretion, and exhales a fœtid odour.
- Stupor, with opisthotonic convulsions, or delirium; pupil dilates.
- Death usually within eight or ten days in man, preceded by great & sudden fall of temperature—25° in the last twenty-four hours.

POST-MORTEM APPEARANCES (Common to Man & Beast).

Skin pale, dry, and wrinkled.

Body has lost from $\frac{1}{5}$ to $\frac{2}{5}$ of its weight; sometimes as much as $\frac{1}{2}$; $\frac{9}{10}$ of the fat, and $\frac{3}{4}$ of the blood have disappeared. The larger glands, spleen, liver, pancreas, have lost from $\frac{5}{10}$ to $\frac{7}{10}$; the heart has lost about $\frac{4}{10}$, the lungs about $\frac{2}{10}$, the nerve-centres only about $\frac{1}{50}$. – The vascularity of these latter organs is normal; all the others are anæmic. The large vessels are bloodless & collapsed.

The stomach & intestine are empty & contracted; their coats are thinned – those of the intestine are sometimes almost transparent, – and their mucous membrane is frequently ulcerated.

The gall-bladder is distended, and the adjoining parts are tinged with bile.

Occasionally the eyes are open, and the conjunctiva intensely red. The mucous membrane of the lips & anus are sometimes similarly inflamed.

Decomposition sets in quickly.

ADDITIONAL NOTES – Death seems to result from the lowering of the temperature consequent upon the exhaustion of the supply of combustible material, *i. e.*, fat; scarcely any fat is to be found, except in the brain. The duration of life, and also the amount of weight lost, are mainly dependent therefore upon the amount of fat previously accumulated in the cellular & other tissues. – Up to the time of death the whole energy of nutrition appears to be concentrated on the nerve-centres. – Young animals, whose nutritive functions are more active, die sooner than adults; cold-blooded animals may live several months without food.

If water can be obtained, life is prolonged, at least in the case of man, – sometimes for two or three weeks. – A supply of water scarcely prolongs the life of animals, though it diminishes somewhat the dessication of the tissues.

SECRETION.

SECRETION in GENERAL

Is the process by which materials are separated from the blood for the purpose either of serving some special office, or of being discharged. Secretions may therefore be divided into secretions proper & excretions.

The secretions proper do not pre-exist in the blood, but originate in the very act of secretion. The excretions, on the contrary, consist of substances which, at least to a great extent, are found ready formed in the blood.

The act of secretion proper consists in the production & subsequent exuviation of cells, which may be considered to stand in the relation of epithelial-cells to those prolongations of skin or mucous membrane, which form the secreting follicles.

In its typical forms—cutaneous perspiration, lachrymal fluid—excretion proper is little more than a mere process of transudation or dialysis: in the excreted fluid no exuviated cells are detected, nor does the epithelial lining of the glandular tubes show sign of active change. Even in these cases, however, and *a fortiori* in the less typical forms of excretion, it must be admitted that the gland-cells are adapted to separate from the blood products of a certain kind only. There is therefore no absolute distinction between secretion & excretion; neither is there, in fact, any essential difference between secretion and the ordinary processes of nutrition: both are effected by the production & subsequent agency of cells, whose functions are more or less transitory.

The solids eliminated in the secretions consist to a great extent of the albuminoid materials of the blood, either but slightly modified and not lowered in chemical composition—casein of the milk,—or in the first stage only of retrograde metamorphosis—the digestive ferments, ptyalin, pepsin, pancreatin, etc. The solids eliminated in the secretions are, on the contrary, non-nutritive & non-organisable, of simple atomic constitution, and usually crystalisable.

For influence of the Nervous System over the Process of Secretion, Vide " Functions of the Sympathetic."

Ductless

THE VASCULAR or BLOODLESS GLANDS.

(Spleen, Thymus & Thyroid Bodies, and Supra-renal Capsules.)

Probably fill the same functions with regard to the blood vessels as do the lymphatic glands with regard to the lymphatics & lacteals: as the latter restore to the lymph & chyle any substances they withdraw from them, so do also the former with regard to the blood.

They probably elaborate the albuminous or formative materials of the blood. This is indicated by the finely granular aspect of the albuminous plasma they contain.

They probably supply the germs of the white or lymph corpuscles, and of those corpuscles which ultimately become converted into red blood corpuscles. This is indicated by the large number of nucleated & non-nucleated cells and free nuclei contained in the above plasma. Leucocythemia also is almost always associated with hypertrophy of one or other of these bodies.

They are largest & most active during embryonic life & childhood, and when the nutritive functions are most actively carried on; the thymus indeed begins to waste after the second year.

For further details see "Functions of the Spleen."

FUNCTIONS of the SKIN—1st Tablet.

The skin may be described as: –

1. A *tough, flexible, & highly elastic covering,* which serves for the protection of the deeper structures.
2. The *principal seat of the sense of touch.*
3. An *important excretory organ.*
4. An *absorbing organ.*

CUTANEOUS EXCRETIONS:

The cutaneous excretions consist of the *secretions* of the *sebaceous & sudoriparous glands* and *hair follicles,* of a large amount of *watery vapour* probably excreted by simple transudation, and of a relatively small amount of *carbonic acid gas.*

Secretions of the Sebaceous Glands & Hair Follicles – The two cannot be separated, since the ducts of the sebaceous glands usually open into the hair follicles. – They consist of *cast off epithelial cells* with various *nuclei & granules,* together with *oily & extractive matters,* and, in certain parts, a *peculiar odorous principle.* – These secretions keep up the softness and flexibility of the skin & hair.

Secretion of the Sudoriparous Glands, and Watery Vapour excreted by Simple Transudation (The two cannot be estimated separately). – The fluid secreted by the sudoriparous glands contains *water, acetic, butyric & formic acids, urea, & salts* (of which the chlorides of sodium & potassium are by far the most abundant), and a little *fatty matter,* which is probably derived from the sebaceous glands. – This fluid is usually formed so gradually that its watery portion disappears by evaporation as fast as it is poured out; the perspiration is then said to bs "*insensible.*" The perspiration is said to be "*sensible*" when, from being more abundant through exercise or exposure to heat, or through the evaporation being arrested, it collects on the surface of the skin in the shape of drops of fluid. – The *quantity* of watery vapour excreted by the skin is greatly influenced by the external temperature, and the state of dryness or moisture, or of stillness or motion of the atmosphere; it is, on an average, *once & a half that excreted by the lungs* in the same time, the mean average being 11 grains a minute (7 grains being erected by the lungs – Lavoisier & Sequin), or $1\frac{3}{4}$ lbs. a day. – It appears almost impossible that such an amount be evaporated from off the surface of the sudoriparous glands only, the total evaporating surface of which is not estimated at more than eight square inches; it is believed, therefore, that a large proportion of the water passes through the cuticle by *simple transudation.*

Evaporating Surface of Body = 8 sqr inches
Work done = 1 3/4 lbs

Carbonic Acid – Is *abundantly* excreted in the lower animals, more particularly in the *naked amphibia,* such as frogs & toads. Frogs will continue to live, and to excrete carbonic acid through their skin, for several hours after their lungs have been tied and cut out. – The cutaneous exhalation of carbonic acid is also considerable in the *higher animals,* for if in these the skin be covered with an *impermeable varnish,* or the body be enclosed in a coutchouc bag, the head alone being left out, the animals soon die *as if asphyxiated,* the heart & lungs becoming gorged with dark blood and the temperature falling by several degrees. – In man the cutaneous exhalation of carbonic acid is $\frac{1}{50}$th (Regnault & Reisset), or even $\frac{1}{38}$th (Scharling & Hanover), of the pulmonary.

FUNCTIONS of the SKIN—2nd Tablet.

ABSORPTION BY THE SKIN.

The skin is continually absorbing *oxygen* from the air, and may be made to absorb *water, metallic & other preparations, divers gases,* etc.

Oxygen. – The quantity of oxygen absorbed by the skin is *very considerable* in the *naked amphibia,* and probably corresponds in those animals to the quantity of carbonic acid excreted in the same time. In the *higher animals* it is *much less,* even less, perhaps, than the quantity of carbonic acid excreted.

Water. – Though for a long while a disputed point, the absorption of water by the skin is now clearly made out. The *body* rapidly *increases in weight* when immersed *in a bath* the *temperature of which is lower than its own.* When, however, the temperature of the bath is higher than that of the body the latter loses weight, for the excretions by the skin & lungs are then so far increased as to outweigh the absorption (Béclard); the apparently contradictory results of former experiments are thus explained. Immersion into cold or tepid water is a means of assuaging thirst.

Metallic & other Preparations – Are easily absorbed through the skin, especially when, by the action of *rubbing* they are partly conveyed into the orifices of the glands; when rubbed into the skin potassio-tartrate of antimony excites vomiting, croton oil purges, the preparations of arsenic, lead, etc., produce their poisonous effects; mercury is thus administered in many cases of syphilis.

Divers Gases. – When the hand is held in oxygen, nitrogen, carbonic acid, suphuretted hydrogen, etc., contained in glass jars over mercury, the volume of the gases rapidly diminishes.

THE URINARY EXCRETION.

Urine is an *excrementitious fluid* by which are eliminated from the body: – the

Superfluous water of the blood;
Saline compounds introduced into the system or generated therein;
Effete azotised products of the respiratory combustion, resulting from the disintegration of the blood & tissues;
Also some non-nitrogenous respiratory products, which are especially abundant when either respiration or the action of the liver is insufficient.

The *formation of urine* in the kidneys is *incessant, as is also its passage into the bladder*. This was shown long ago in animals by the uninterrupted flow of urine which is seen to pass from the ureters when they are withdrawn from the abdomen & divided, and has been demonstrated more recently by Stehberger and Erichsen in cases of *ectopia vesicæ* in man. During fasting two or three drops of urine per minute are then seen to pass from the ureter into the bladder, each drop momentarily raising the papilla on which the ureter opens. In the recumbent position the regular & incessant dropping is replaced by less time-regulated jets, the urine first accumulating in the ureters, and being expelled only when these contract, or when external pressure is brought to bear upon them, as in coughing or straining, or in deep inspirations. A short time after drinking freely the urine passes from the ureters in an almost continuous stream.

The urine *accumulates in the bladder*, the distention of which is felt, by a transferred sensation, at or near the end of the penis, and from whence it is voided by the partly voluntary and partly reflex contraction both of the abdominal muscles & of the muscular walls of the bladder. These latter contain non-striated fibres only, and though supplied to a great extent by spinal nerves, they contract but slowly under the influence of the will.

Under ordinary circumstances the escape of urine is prevented by the *moderate (tonic) contraction of the sphincter vesicæ*, the fibres of which, as well as the other muscular fibres of the bladder, are under the influence of the *vesical centre* contained in the lumbar portion of the cord: – This sphincter will usually resist the pressure of a column of water of from 18 inches in height (rabbit) to 30 inches (dog); but if the vesical centre be destroyed, or the vesical nerves divided, less than a quarter of that pressure will suffice to overcome the resistance (Kupressow).

Regurgitation of urine into the ureters is prevented by the valvular disposition of the openings of the latter due to their passing obliquely for from ½ to ¾ of an inch between the muscular and mucous coats of the bladder; this obliquity being maintained, according to Sir C. Bell, by two bundles of fibres, the so-called *muscles of the ureters*, which, arising from a little behind the openings of the latter, converge to be inserted into the back of the middle lobe of the prostate.

PHYSICAL PROPERTIES of URINE.

Urine is a *watery* fluid of a *pale yellow*, or sometimes of a brownish or deep orange colour; *limpid*, though, as it cools, often becoming opaque and turbid, and, in disease, being frequently so when voided; *acid*, but becoming rapidly alkaline by decomposition. – The urine of *carnivorous animals* resembles that of man, but that of *herbivorous animals* is normally alkaline & turbid. The difference is occasioned by the large proportion of alkaline salts contained in vegetable diet, and ceases when herbivorous animals are restricted to animal diet, while, on the other hand, alkalinity and turbidity of the urine immediately appear when the reverse experiment is tried (Bernard).

The *acidity* of the urine is probably *due* to the large quantity of *acid phosphates* it contains. This acidity *diminishes*, and even sometimes disappears, *a few hours after a meal*, especially when much animal food has been taken, and a correspondingly large proportion of the acid gastric secretion is required to digest it (Bence Jones).

The normal average *specific gravity* of human urine is 1020, and the normal average *quantity* voided daily is 52 ounces. Both vary, however, to a very great extent coincidently with the quantity of fluid recently absorbed, remaining nevertheless inversely proportionate one to the other. – The *urina potus*, which is excreted shortly after much drink has been taken, is extremely abundant, pale, and light. The *urina cibi* excreted shortly after a meal, contains more of the solid constituents, and is darker and heavier. The *urina sanguinis* formed when neither food nor drink has been recently taken, is *intermediate between the two*, and is also unmixed with elements accidentally derived from the food or drink; such is the urine *excreted* from the kidney *in the morning*. The urine *first voided in the morning* has however been condensed by a long sojourn in the bladder, and is the richest in solid materials and the heaviest of all.

The *quantity* of urine *voided* is *greater*, and its *specific gravity* proportionately *less*, *in winter* than in summer, less water being excreted by the skin and lungs in the former season than in the latter.

CHEMICAL COMPOSITION of URINE—1st Tablet.

Urine consists of water holding in solution from 2 *to* 7 *per cent. of solid substances;* the two extreme proportions corresponding respectively to the *urina potus* and to the *condensed urine first voided in the morning.*

The *absolute quantity of solid substances* excreted daily is much more constant, only varying normally *between* 2 *and* 3 *ounces.*

The *water* is believed to be separated from the blood by mere *transudation,* and it is conjectured that this transudation takes place more particularly in the *Malpighian bodies,* into which the vascular tufts or glomeruli project naked (Bowman), or covered at most with a thin layer of squamous epithelium.

The *solid constituents* are believed to be excreted principally through the *spheroidal epithelium of the tubes.*

These solid constituents are *urea, uric acid, hippuric acid, nitrogenous & non-nitrogenous extractive matters, mucus, colouring matter, salts, & medicinal or other substances* taken with the food or drink.

Urea – Vide next Tablet.

Uric Acid – $C_{10}H_4N_4O_6$ – Averages 8 grs. daily. Is partly in a free state, and partly combined with the alkaline phosphates.

It is a nitrogenous compound *less oxidised than urea.* Its proportion in the urine depends, therefore, on the one hand, on the greater or less quantity of nitrogenous food taken, or the more or less rapid disintegration of the tissues, and, on the other hand, on the greater or less activity of the respiratory functions: – It is *increased* by a *highly albuminous diet,* and in all *febrile conditions.* It is *diminished* by *active out-door exercise;* it was increased, however, during some of Mr. Weston's walks in the Agricultural Hall (Ashburton Thompson). It is abundant in the urine of reptiles, and of the gluttonous flesh- & fish-eating birds.

It is precipitated from the urine by acids, and, when in excess, by cooling. It then forms variously shaped crystals more or less tinged with the colouring matter of the urine.

Hippuric Acid – Averages 15 grs. daily; is less oxidised, but also less nitrogenous than either urea or uric acid. It is principally derived from *vegetable diet,* and is abundant in the urine of the horse and of all herbivorous animals, especially when they are at work. When benzoic acid is taken it is excreted in the shape of hippuric acid.

Extractive Matters – The principal nitrogenous extractive matters are *Kreatin* & Kreatinin,* which are both crystallisable substances less oxidised than either urea or uric acid, and probably the first products of decomposition of syntonin or muscular fibrin. Among the still simpler forms to which animal matter is reduced by the respiratory process, which simpler forms are more or less constantly found in the urine, are *xanthin, cystin, oxalic acid* (the latter when the respiratory process is considerably disturbed), *benzoic, lactic, & various volatile acids,* & small quantities of *carbonic acid & nitrogen.*

* *Kreatin* is said not to exist in fresh urine, and to result merely from the Kreatinin taking up an additional equivalent of water. – Kreatin is a neutral substance, Kreatinin is a powerful base.

Colouring Matter – Termed *uro-hæmatin* (Harley). Contains iron, and is separable into red, blue, yellow and colouring matters; it is probably derived from the biliary acids, the injection of which into the blood increases the quantity of the urinary colouring matter.

Mucus – Healthy urine contains a few epithelial cells. When the mucus is more abundant it forms a cloud on cooling; when it is very abundant it causes the urine to decompose while still in the bladder.

Salts – From ½ to ⅔ of an ounce daily. Are mainly sulphates, bi-phosphates & chlorides of soda, potash, ammonia, lime & magnesia; the sulphates forming nearly ½, and the phosphates & chlorides each about ¼ of the total mass of the salts. The *sulphates & phosphates* are *mainly formed in the system* by oxidation of the sulphur & phosphorus of the food and tissues, and by the combination of the newly-formed acids with those alkalies which were previously combined with the weaker acids; their amount in the urine is *mainly dependent* therefore upon the rate of *organic disintegration.* The *phosphates* are rendered acid phosphates or bi-phosphates by the appropriation of the bases by the sulphuric, uric, hippuric & other acids above mentioned. Their proportion appears to be *closely related to the amount of nervous activity* displayed, a circumstance not to be wondered at when we consider the amount of phosphorus contained in nervous tissue and necessarily set free by its disintegration. The earthy phosphates bear but a small proportion to the alkaline, varying in amount with the quantity of earthy salts contained in the food. The *chlorides* are mainly derived from the food; of the chloride of sodium ingested, a part is decomposed in the system, whereby hydrochloric acid is supplied to the gastric juice, and soda to the bile; much of the hydrochloric acid must however reunite with its base in the alimentary canal, and then doubtless be reabsorbed with the products of digestion.

CHEMICAL COMPOSITION of URINE—2nd Tablet.

Urea – CH_4N_2O – Averages upwards of an ounce daily in the male adult, and thus forms nearly one half of all the solids of the urine.

Chemically, it is identical in composition with cyanate of ammonia; or it may be considered as the amide of carbonic acid.

Physiologically, it is the most completely oxidised introgenous substance found in or derived from the body.

It proceeds mainly from the disintegration of the nitrogenous constituents of the blood, partly from the disintegration of the tissues generally, the muscular tissue being perhaps excepted. – There is no good reason for believing that it is especially formed in the kidney: – it is found in the blood (2 to 4 parts in 10,000), and is more abundant in the renal artery than in the renal vein; it accumulates in the blood just as much when the kidneys are extirpated as when the ureters are tied.

Its precise amount depends mainly on the alimentation, but it is influenced by *muscular exercise, age, sex, climate, time of day, & disease.*

97 p.c. N.
N.F. = 22

Alimentation – 97 per cent. or more of the nitrogen consumed in the food is eliminated by the kidney in the form of urea (Parkes). The quantity eliminated is increased a few hours after each meal, especially if much animal food has been taken, and is diminished by fasting. The exhibition of common salt, or of mineral acids, and the drinking of large quantities of water, increase the quantity eliminated; arsenic & alcohol diminish it. – During *total* abstinence a little more urea is eliminated than when either starch, sugar, or fat is allowed.

Exercise – Facts are opposed to the supposition that muscular tissue is materially disintegrated during exercise, and in favour of the view that the force developed by muscle proceeds from the oxidation of the hydrocarbonaceous constituents of the blood, the heat derived from which oxidation is converted by the muscles into mechanical force: – the quantity of urea excreted is but slightly increased by any moderate exercise. During unusually severe exercise, however, a distinct consumption of muscular tissue is manifest. This was clearly proved by the great increase of urea in Mr. Weston's urine during each of his walks in the Agricultural Hall (Ashburton Thompson).

Age – Before the age of 6 or 7 the quantity of urea eliminated is more than double in proportion to the body-weight; the quantity diminishes a little in old age.

Sex – In females the quantity is a little less in proportion to the body-weight; it is further diminished during menstruation.

Climate – The quantity is greatest in cold climates, and in winter & dry weather.

Time of Day – The quantity diminishes from morning to evening, being temporarily increased, however, after meals – especially after breakfast & tea.

Disease – The quantity increases greatly in the early stages of all inflammatory diseases, in concidence with the rapid disintegration of the albuminoids, which disintegration leads to elevation of temperature. When the fever subsides the quantity falls sometimes below the average, most of the nitrogen of the food being appropriated to the repair of the wasted tissues. – The quantity is somewhat diminished in all chronic affections which impair nutrition.

ANIMAL ELECTRICITY, NERVES IN GENERAL.

NOTE.

December, 1876.

The Tablets on Physiology were very nearly completed in July last, except as regards the functions of the Brain; and the work, as it now stands, might have been published at the commencement of the present session.

With regard to the functions of the Brain the Author was stopped for a time by a somewhat serious obstacle. On the one hand he was desirous not to shirk the difficulties involved in the consideration of the functions of that organ; and, on the other, he was unwilling to adopt the disheartening conclusions come to by prominent writers of the day.

He determined, therefore, first, to review the whole subject of the bearings of Physiology on Psychology, Religion, & Morals; secondly, as he could boast of no personal authority in such matters, to lay before his readers *in the very words, condensed but not altered*—and therefore with the Authority—of the Authors themselves, the facts of every "case" worthy of separate investigation, and the arguments urged in its defence; thirdly, to arrange these "condensed quotations" in the form of an argument or debate. The reader would be interested, he thought, by the varied aspects of such a work; and, if the scheme were properly carried out, no writer could well complain of being ill-treated, for his *ipsissima verba* could not misrepresent his views.

NOTE.

December, 1877.

The Tablets on pages 75, 76, 77, 78, & 79, are but a fragment of "MENTAL PHYSIOLOGY" comprising I. "CEREBRAL PHYSIOLOGY EXPERIMENTAL & INDUCTIVE," II. "PSYCHOLOGY, RELIGION, & MORALS FROM A PHYSIOLOGICAL POINT OF VIEW," a work (the one above alluded to) upon which the Author was engaged when his School of Anatomy in New Bridge Street, was forcibly broken up.

The Author hopes to be able to complete and publish the above work at no very distant date.

Among the conclusions of the "debate" are the following:—

"I believe no opinion advanced in modern times will prove to be more incorrect, less justified by facts, or found to be further removed from the truth, than that adopted by Straus:—that Scientific Men who are frank, honest, and upright, will be obliged to acknowledge that they are no longer Christians. Modern Science has not proved anything which tends in any way to shake our faith in God, or to destroy our belief that miracles have been performed." (LIONEL S. BEALE.)

"That any *antagonism* should be supposed to exist between those 'Laws' which express the Uniformities of Nature discovered by Science, and the Will of the Author of Nature as manifested in those uniformities,—so as for the acceptance of the former to exclude the notion of the latter,—can only arise either from an unworthy conception of the Deity as an arbitrary and capricious ruler, or from an unphilosophical conception of the real meaning of Science." (W. B. CARPENTER).

"He who reflects upon himself and upon the universe is forced in the end to the recognition, in the workings of the world, of a power from which all life and energy proceed, which has been from the beginning, is now, and, so far as we can see, ever shall be, and which cannot be comprehended and controlled by human thought and will, but comprehends and controls human thought and will. We recognize an impulse outside ourselves, working also in our wills, which is the moving energy of the evolution which went on through countless ages before man appeared upon earth, which is going on now in his progress, and which will doubtless go on through countless ages after he has ceased to replenish the earth and subdue it. We come back indeed to something which, however we name it, or forbear to name it, is very like the theological Trinity—God the Unrevealed and Unrevealable, God the Revealed, and God the Revealer." (H. MAUDSLEY).

"There is a sort of dim feeling in many a young heart that old opinions are untenable, or, if to any extent tenable, will have to be totally reconstructed—that the attack is overwhelmingly strong, and the defence very weak—and that it is quite excusable to cast out the four anchors of the soul—its hope, its faith, its reverence, and its love—on the old sand-bank of simple morality, and to wait."

"With minds thus circumstanced, no argument is probably more likely to carry real influence with it than this—that *the truest science* is now plainly taking the other side, and *is unmistakably declaring for the truth of Theism, and for the belief in a Creator and moral Governor.* Science is rapidly getting rid of its crudities; it has sown, so to speak, its wild oats of speculation, and is now fast approaching a state in which, by the over-ruling wisdom of the All-wise Creator, it will be found, more than ever before, to sustain all the fundamental teaching of Revelation." (BISHOP OF GLOUCESTER & BRISTOL).

ACTION of ELECTRIC CURRENTS on MUSCLES and NERVES.

Induced or Interrupted Currents – Act as *stimuli.*

Continuous Currents – Act as *stimuli* only *at their make or at their break,* or when their intensity is suddenly increased or diminished. – During their passage through a nerve they modify its physiological properties by inducing the state of *electrotonus* (Vide two following Tablets).

As stimuli, induced currents are much more powerful than continuous currents, because of their short duration & high tension; this is *especially* the case with the *opening current,* which is of shorter duration & higher tension than the closing current. – When an interrupted current is used, or when the interruptions of a continuous current exceed twenty per second, the muscle has not time to relax between the periods of making and breaking contact; it therefore passes into a state of continuous contraction, or *tetanus.*

ACTION of ELECTRIC CURRENTS as PHYSIOLOGICAL MODIFIERS.

ELECTROTONUS.

During its passage through *any portion of the length of a nerve*, an electric current induces along the whole length of that nerve a condition termed *electrotonus*, in which condition the *excitability*, *conductibility*, & *electro-motor phenomena* of the nerve are modified as follows:—

Excitability & Conductibility – Are *increased* in the portion of the nerve adjoining the cathode *(cathelectrotonus)*, and *diminished* in the portion adjoining the anode *(anelectrotonus)*; the neutral point, or point of indifference, lying between the electrodes, in the vicinity of the anode if the electrotonising current is weak, in the vicinity of the cathode if the electrotonising current is strong. – Any mechanical or chemical stimulus, or a second electric current, may be used to test the excitability of the electrotonised nerve.

Electro-Motor Phenomena – The "natural nervous current" is *increased*, *if* it *coincide* in direction with the *electrotonising current*, *diminished or reversed*, *if* it be *of opposite direction*. – If the electrotonising current be applied to the central part of the nerve, the "natural current" will be *increased* in the portion of the nerve adjoining the *anode*, *diminished* in the portion of the nerve adjoining the *cathode*.

If electrotonus be divided into *centripetal* & *centrifugal* according to the direction of the electrotonising current, and if an electrotonised nerve be divided with Pflüger into the *three following regions*: –

Intra-Polar – Comprised between the electrodes;

Central Extra-Polar – Comprised between the nerve-centres & the intra-polar region;

Distal Extra-Polar (sometimes called Myopolar) – Comprised between the intra-polar region & the muscles; –

the *excitability & conductibility* of the electrotonised nerve may be said to be

Increased in { *Central Centripetal* & *Distal Centrifugal* } *extra-polar electrotonus*, and in an adjoining portion of the intra-polar region relatively large if the electrotonising current be weak, relatively small if the electrotonising current be strong.

Diminished in { *Central Centrifugal* & *Distal Centripetal* } *extra-polar electrotonus*, and in an adjoining portion of the intra-polar region relatively small of the electrotonising current be weak, relatively large if the electrotonising current be strong.

The electrotonic influence varies in proportion to the *strength* of the electrotonising current, & to the *length of nerve traversed* by it, and is always most marked in the *vicinity of the poles*; if, however, a current of unusual strength be used, the phenomena become less marked, or even disappear. The phenomena are momentarily reversed when the electrotonising current is suppressed, but the nerve soon returns to its normal condition.

The *electro-motor* phenomena are the same with sensory nerves as with motor nerves.

EXPLANATIONS of the PHENOMENON of ELECTRO-TONUS.

Two explanations are given:

1. – *It is a vital phenomenon:* – The natural or proper electro-motor action of the nerve is increased in anelectrotonus, diminished in cathelectrotonus (Du Bois-Reymond); the excitability & conductibility of the nerve are increased when its molecules pass from their ordinary condition to one of greater mobility *(cathelectrotonus)*, diminished when its molecules pass from their ordinary condition to one of less mobility *(anelectrotonus)* (Cyon).

2. – *It is a purely physico-chemical phenomenon:* – The passage of an electric current through a nerve induces an *electrolytic action*, which generates acids round the anode, alkalies round the cathode; the acids lower the excitability of the nerve, the alkalies increase it (Herman & Onimus). – *Any bad conductor*, cotton or silk thread moistened with water or saliva, gutta-percha cord, a strip of intestine, etc., *may be substituted for the nerve* in the experiments on electrotonus, and the same electro-motor phenomena will be observed; if a good conductor, such as a wire, be used, the electro-motor phenomena will not be observed. In the case of a bad conductor *free electricity* overflows towards the galvanometer, and traverses the coil, and it is this free electricity which acts upon the needle: – On the one hand, whenever the needle has deviated, free electricity can be demonstrated in the vicinity of the poles of the electrotonising current; on the other hand, if frictional electricity be applied to the nerve when the needle is at rest, the needle will immediately be seen to move. – The *positive charge* in the vicinity of the anode *agreeing* with, and the *negative charge* in the vicinity of the cathode *disagreeing* with, the *natural electric condition of the nerve at rest*, the excitability of the nerve is diminished in the one case, and increased in the other (Radcliffe).

N. – The balance of evidence is clearly on the side of Dr. Radcliffe's views.

ACTION of the ELECTRIC STIMULUS (INDUCED or INTERRUPTED CURRENTS) on MUSCLES and NERVES.—1st Tablet.

Both Electrodes being applied to the Nerve.

It is *only at the make & at the break* (or when its intensity is suddenly increased or diminished) that a continuous current excites either a nerve or a muscle.

The *make excitation* (or the increase excitation) is, all things alike, *the more powerful* of the two, and is *most marked at the cathode (appearance of cathelectrotonus)*. The *break excitation* (or the decrease excitation) is, all things alike, the *less powerful* of the two, and is *most marked at the anode (disappearance of anelectrotonus)*.

If, under ordinary circumstances, a current of varying intensity be applied to a motor nerve, the following results will ensue *(Law of Pfluger)*: –

Weak Current: –

Contraction at the make only, whether the current be ascending or whether it be descending – For a stronger current would be necessary to induce contraction at the break, since the break excitation is less powerful than the make excitation.

Medium Current: –

Contraction both at the make and at the break, whether the current be ascending or whether it be descending.

Strong Current: –

Contraction at the make only, if the current be descending, at the break only if the current be ascending – For, in this case, the *diminished conductibility of the anelectrotonised portion* of the nerve (Vide Electrotonus) *prevents* the *transmission* towards the muscle both of the break excitation at the anode, in the case of the descending current, and of the make excitation at the cathode, in the case of the ascending current.

The *conditions which favour or prevent contraction* of a muscle, when a current is transmitted through its nerve, are, however, *somewhat complex*: –

During life, nerves are most excitable in the vicinity of the nerve-centres, or at a distance from the muscles. – Therefore, in a living animal, or in an animal recently killed, and with a current of ordinary intensity, –

(1) The *closure of the ascending current is a more powerful stimulus than the closure of the descending current,* and the *opening of the ascending current is a less powerful stimulus than the opening of the descending current.*

(2) In the case of the *ascending current,* the *make excitation* is a *more powerful stimulus than the break excitation*; for not only is the former in itself a more powerful stimulus, but it acts on a more excitable portion of the nerve (at a greater distance from the muscles).

(3) In the case of the *descending current,* the *make excitation, in itself a more powerful stimulus, acts on a less excitable portion of the nerve* (nearer the muscles); while the *break excitation, in itself a less powerful stimulus, acts on a more excitable portion* of the nerve (nearer the nerve-centres). The *break excitation, though usually the weaker, may, therefore, sometimes become the stronger.* – This happens under certain conditions, which do not appear to be as yet very clearly defined, but which the Author believes to be connected with the point of application of the electrodes to the nerve (Vide below). –

Immediately after death the *excitability* of a nerve is for a short time *considerably increased,* the *duration of the period of increased excitability* being *proportionate,* in any given portion of the nerve, *to the degree of proximity to the muscles.*

After this period of increased excitability, the *excitability* of the nerve *dies out slowly from the nerve-centres to the periphery.*

Therefore the degree of *excitability* of a nerve varies in its several portions, being *greatest first in one portion,* and *then in another,* and the influence of the *point of application of the electrodes* to the nerve (distance of the part irritated from the muscle, on the one hand, from the nerve-centres on the other; and distance between the two electrodes) should be taken into consideration in experimental research. This, it is believed, has hitherto been overlooked.

The influence of the *freshness of the nerve* experimented on has been carefully studied by Ritter, Nobili, & Onimus; Ritter's Contraction-Table is divided into six periods, Nobili's into four, and Onimus's into five. – These Contraction-Tables present many points of resemblance with each other, and with Pflüger's Table above described: –

(1) Descending these Tables from that period (third of Ritter, first of Nobili & Onimus,) in which the exciting current, whether it be ascending or descending, gives rise to a contraction *both at the make & at the break,* we find in each Table that, while *the power of both* the make excitation & the break excitation *diminishes absolutely,* that of the *make excitation increases relatively* to that of the break excitation, *if the exciting current be descending,* while that of the *break excitation increases relatively* to that of the make excitation, *if the exciting current be ascending*: – the *break contraction* disappears first in the former case; the *make contraction* disappears first in the latter case. – It will immediately be seen that this agrees with the fact above-mentioned that, after death, the excitability of a nerve dies out slowly from the nerve-centres to the periphery: both the *make excitation* of the *descending current* and the *break excitation* of the *ascending current* affect the nerve *in its peripheral portion.*

(2) If, now, we ascend Ritter's Table from the same starting point, we find that, *at the very first,* that is to say, directly the nerve is excised from the living body and for a few moments afterwards, the *make excitation* is the *stronger* in the case of the *ascending current,* and the *break excitation* the *stronger* in the case of the *descending current.*

That the *break excitation* of the *descending current* should, *at the very first,* be a stronger stimulus than the make excitation of the same current, – which make excitation subsequently becomes the stronger of the two, – appears to the Author to be due to the *extent (greater immediately after death) of that distal portion of the nerve whose excitability is temporarily increased;* if the electrodes be suitably placed, *i.e.*, neither too near the muscle, nor too far from it, the *break excitation* would, in the first case, affect the nerve *at a distance from the muscle, but still within the limits of that portion of the nerve whose excitability is temporarily increased.*

That the *break excitation* should be the *stronger, first with the descending current,* and *afterwards with the ascending current* appears to the Author to be due, as regards the descending current, to the extent (greater immediately after death) of that distal portion of the nerve, whose excitability is, in the first instance, increased; and as regards the ascending current, to the *diminished excitability of the central portion of the nerve.* In the first case, if the electrodes are suitably placed, the break excitation would affect the nerve at a distance from the muscles, but still within the limits of the portion of the nerve whose excitability is temporarily increased; in the second case, the break excitation would affect the nerve in that *portion adjoining the muscles, whose excitability is, after a time, less impaired than that of the central portion.* – Further experiments in the direction above suggested would be necessary, however, to clear up this point.

ACTION of the ELECTRIC STIMULUS (INDUCED or INTERRUPTED CURRENTS) on MUSCLES and NERVES.—2nd Tablet.

One Electrode being applied to the Muscle, & the other to the Nerve.

A nerve being more excitable than the muscle which it supplies, the *strongest muscular contraction* will occur, when the *stronger stimulus, i.e.,* either the make excitation at the cathode (make of the ascending current) or the break excitation at the anode (break of the descending current) is *applied to the nerve.* The *muscular contraction* will be *less marked,* or will not take place at all unless the part be very fresh, *when the weaker stimulus, i.e.,* either the make excitation at the anode (make of the descending current), or the break excitation at the cathode (break of the ascending current) *is applied.*

Both Electrodes being applied to the Muscle.

As long as a muscle retains its excitability it will contract upon the direct application of the electric stimulus. "But as changes take place more slowly in muscle than in nerve, *length of duration of the stimulating current* is more necessary in the former than in the latter for the production of stimulation. Hence all induction-currents, and the more transitory constant currents, are unable to stimulate to contraction muscle deprived of its nervous connections by curare, while they are able to cause contractions in muscle by acting upon its motor nerve (Brücke)." (Hermann, translated by Dr. Gamgee).

"In the electric stimulation of muscles, the same laws hold as in that of nerves. Here also it is only variations in currents that produce *stimulation,* which, as before, *proceeds, on closing, from the cathode,* and, *on opening, from the anode* (Von Bezold) : – If the electrodes be placed at the thin edges of a piece of flat muscle split along a portion of its length (in the shape of a pair of trousers), contraction follows, on the application of a moderate current, in the strip next the cathode on closing, in that next the anode on opening. If the muscle be not split, it bends for the same reason, on closure towards the cathode, and on opening towards the anode." (Hermann, translated by Dr. Gamgee).

ANIMAL ELECTRICITY.

Muscles, nerves, and other parts of the body are electro-motor.

When the *natural surface* of a muscle or nerve is connected by means of the wire of an electrometor to its *transverse cut surface,* a current is found to pass along the wire *from the former to the latter,* if the muscle or nerve be at rest. And muscular batteries may be constructed by joining several segments of a skinned frog's leg in such a way that to the natural & the cut surfaces of each segment correspond the cut & the natural surfaces of the adjoining ones; if now two points of the sciatic nerve of a prepared frog's leg be brought into contact with the natural & cut surfaces of the terminal segments of the battery, the muscles of such prepared leg will be seen to contract. – The *artificial longitudinal surface* of a muscle (the muscle being split up in the direction of its fibres) may take the place of the natural surface, and the transverse cut surface may generally be replaced by the *tendon*; in this latter case, however, the current is much weaker, and is sometimes even reversed *(par-electronomy).*

It may be added that, on the longitudinal surface either natural or artificial, any point nearer the middle of the muscle is positive to any point nearer the extremity, and that, on the transverse cut surface, any point nearer the centre is negative to any point nearer the periphery.

When a muscle or a nerve is excited, its natural current suddenly diminishes or ceases, and may even be reversed (negative variation); and if the nerve of a prepared frog's leg be made to rest at the time upon the excited muscle or nerve, an induction current will pass through the nerve of such prepared frog's leg, and will throw the leg into contraction; further, this prepared frog's leg may similarly act upon another prepared frog's leg, which latter may act upon another one, and so on.

In explanation of the above facts, muscles & nerves have been supposed to be made up of *parallel series of minute electro-motor elements each possessing,* when at rest, *an equatorial belt manifesting positive electricity and two polar regions manifesting negative electricity.* The further supposition that these electro-motor elements are *composed of two molecules* coming in contact with each other by their positive poles, and that the tendon of a muscle rests upon a single layer of these molecules, would explain the phenomenon of par-electronomy.

When a muscle or a nerve is excited, these electro-motor elements would all become *polarised,* all the positive poles being turned in one direction, and all the negative poles in the other direction: – An electric current will be found to traverse a nerve *A* from one end to the other (electrotonus) as soon as even a very small portion of its length is placed between the electrodes of a battery; and the make & break of the current through this very small portion of the nerve *A* will result in induction currents, expressed by muscular twitchings, in the sciatic nerve *B* of a prepared frog's leg brought into proximity to any part whatever of the nerve *A*. The "paradox of contraction" is a phenomenon of this kind.

In *man & the mammalia* the general body current runs *from the centre to the extremities.* – It is weakened by over-exertion, and is temporarily reversed by muscular action: – If both hands be dipped into a basin of water forming part of the circuit of a galvanometer, no deviation of the needle will take place while both arms are at rest, the descending current in one arm counterbalancing that in the other; but if, while one arm is kept at rest, the muscles of the other arm are made to contract, the deviation of the needle will immediately show an ascending current in this latter arm. – In the frog the body current runs from the extremities towards the centre.

The body current, whether it be observed in muscles, nerves, bones, or other structures, is probably due to the *chemical processes of which the tissues are the seat;* the current observed by means of the electrometer is probably but a *derived* current, the resultant of incomparably more intense molecular currents circulating around the ultimate electro-motor elements of the tissues.

THE NERVES AND THEIR ROOTS.

A nerve is *sensory or motor according to its connection with sensory or motor end-organs;* the action of *the nerve-fibres* is the same in either case: they *conduct in both directions.* – This is proved by the following facts:

1. When a nerve is excited its natural electric current suddenly diminishes (or ceases, or may even be reserved) *along its whole length.*

2. If one terminal twig *A* of a forked nerve (tibial or peroneal bifurcation of the great sciatic nerve of the frog) be divided above the muscles it supplies and then be irritated, the muscles supplied by the *other twig B* will immediately be seen to contract. This "*paradoxical contraction*" is thus explained: the irritation of the twig *A* induces a sudden change in the electrical condition of its fibres (diminution, cessation, or negative variation of natural current); this change results in an induction current in the fibres of the twig *B,* as they lie side by side with the former in the forked trunk; this induction current stimulates the corresponding muscles. – That the experiment may be free from all fallacy resulting from reflex action, the trunk of the sciatic nerve should be divided high up, or the spinal cord should be destroyed.

3. MM. Philippeaux & Vulpian *divided the hypoglossal & lingual nerves, and applied the peripheral extremity of the former to the central extremity of the latter;* union took place, and irritation of any part of the resulting trunk induced, on the one hand, manifestations of pain, and, on the other, contraction of the muscles of the tongue.

4. – The *conduction of sensory impressions may actually be reversed:* – The denuded extremity of the tail of a young rat was inserted beneath the integument of the animal's back; it became adherent in this situation, and the tail, when subsequently severed at its base, still continued to show signs of sensibility (P. Bert).

5. – No difference, structural or chemical, has yet been made out between sensory & motor nerves.

Under ordinary circumstances, sensory impressions originate in the action of *external objects* upon the extremities of the nerves, and motor impulses originate in *the will,* or in the *reflex action* of the nerve-centres. – The sine qua non condition of transmission in such cases is the *continuity* of the nerve *from one extremity to the other.* – When, however, a part is supplied by several nerves, or by a nerve formed of fibres derived from several sources, as is the case with nerves emanating from a plexus, the section of any one of these nerves, or the suppression of any one of the sources from which the fibres of each individual nerve are derived, only diminishes the sensibility or the motor power of the parts supplied: – Section of *one of the cords of the brachial plexus* weakens all the muscles of the arm, but does not completely paralyse any. Excision of a portion of the *musculo-spiral nerve* above its anastomosis with the external cutaneous occasions but a slight impairment of sensibility in the outer part of the hand (Savory).

The excitability of the nerves is diminished in anelectrotonos, and increased in cathelectrotonos. It is diminished by cold, compression, mechanical injury to the neighbouring parts; increased by moderate warmth, & vascular congestion. It is temporarily exhausted by shock or repeated excitement. Immediately after death it is for a short time considerably increased, the duration of the period of increase being, in any given portion of the nerve, proportionate to its degree of proximity to the muscles; the excitability then dies out slowly from the centre to the periphery, persisting longer, however, in cold-blooded than in warm-blooded animals. During life the *excitability* of a *motor nerve* diminishes from its origin to its termination, *i.e.*, is *greatest near the n.-centres, least near the muscles.**

Sensory impressions produced by direct irritation of a sensory nerve affect the sensorium as if they had proceeded from the whole area of distribution of the irritated nerve: – Local irritation of the nerves of a stump produces wide felt pain seemingly over all the lost extremity; violent neuralgia of the face may result from a morbid condition of the central part of the 5th nerve. The mind has therefore no power, when a nerve trunk *alone* is irritated, of ascertaining the exact point to which irritation is applied; it is only when the extremities of some of the branches of the nerve, or of some other nerve, are irritated at the same time, that the precise seat of irritation is directly perceptible. – Motor impulses similarly produced excite contractions in all the muscles supplied by branches given off below the irritated point.

The *excitability of the* Roots of the Nerves was established by the celebrated experiments of Sir Charles Bell.

The posterior roots are purely sensory: – Their *irritation* elicits signs of pain, but gives rise to no movements except by reflex action; their *division* destroys sensibility in the parts supplied. Irritation of the *central segment* induces pain & reflex movements; irritation of the *distal segment* produces no effect.

The anterior roots are both motor & slightly sensory: – Their *irritation* induces violent muscular contractions and slight manifestations of pain; their *division* paralyses the muscles supplied. Irritation of the *central segment* produces no effect; irritation of the *distal segment* induces muscular contractions – and pain, *if the posterior roots have not been divided.*

Since irritation of the central segment produces no effect, and since irritation of the distal segment produces pain *only* when the posterior roots are still undivided, it is evident that the *sensibility of the anterior roots* is *either merely apparent, or else derived from the posterior roots through recurrent fibres passing from one root to the other, at or beyond their point of coalescence.*

The former opinion is that of Brown-Séquard, and the pain manifested is attributed by this Author to *compression of the extremities of the sensory nerves by the contracting muscles.* The latter opinion is that of Magendie, Bernard, Longet & others. It is supported by the fact that degenerate nerve-fibres (supposed to be the recurrent fibres in question) are found in the ant. roots a short time after the division of the post. ones (Burdon-Sanderson).

The fact that *division of the posterior roots should destroy the sensibility of the anterior* ones harmonises with both theories. Division of the nerve-trunks *beyond the* point of *coalescence of the roots* is said to produce the same result; this would apparently antagonise the latter theory, unless it be admitted that the recurrence take place in the plexuses (Küss), or even further on (Bernard).

* Some Authors suppose that the stimulus gains strength as it descends (Pflüger); others, attribute the greater excitability of the central portion of the nerve to its being less perfectly protected by a more delicate sheath (H. Power).

THE RATE of NERVOUS CONDUCTION

Averages *in man*: –

Through the Cerebro-Spinal Nerves –

Sensory impressions	47 metres per second.
Motor impulses...	27 „ „

This was shown by Helmholtz, Burckhardt & others by measuring the *interval* which elapses *between the giving of a signal, and the production, in obedience thereto, of a movement previously agreed upon.*

When the rate of transmission of *sensory impressions* was sought for, the signal adopted was the *irritation* of the skin of the *foot, leg, thigh, &c.*, and the movement agreed upon was the *lifting up of a finger;* when the rate of transmission of motor impulses was sought for, the signal adopted was the *ringing of a bell,* and the movement agreed upon was the *contraction of the triceps extensor femoris, tibialis anticus, extensor brevis digitorum, etc.* – The interval comprised in either case: –

1. The *reception* of the impression by the papillæ of the skin, or by the auditory apparatus.
2. The *transmission* of the impression to the sensorium.
3. Its *perception,* and the excitation of the *act of volition.*
4. The *transmission of the motor impulse* to the muscle.
5. The *contraction* of the muscle.

Now, *when the point of application of the stimulus varied* (irritation of the skin of the foot, leg, thigh, &c.), the difference between the intervals recorded marked the time required for the conveyance of the impression through a length of nerve equal to the distance between the foot & the leg, between the leg & the thigh, etc.; – and *when the stimulus remained the same* (the ringing of a bell), the difference between the intervals recorded marked the time required for the conveyance of the motor impulse through a length of nerve equal to the distance between the triceps extensor femoris & the tibialis anticus, between the tibialis anticus & the extensor brevis digitorum, etc.

Through the Spinal Cord –

Sensory impressions	*Tactile,*	42 metres per second.
	Painful	13 „ „
Motor impulses		10 „ „

This was shown by comparing the time required for the conveyance of a sensory impression or a motor impulse from or to the *extremities of nerves arising,* like the sciatic & the ulnar, *from different parts of the spinal cord.* The time required for the conveyance through the nerves being known, the difference, in each experiment, in the duration of the entire passage marked the time required for conveyance through a corresponding length of the cord.

It may be added that these rates of transmission vary slightly in proportion to the intensity of the impression, or to the strength of the impulse, and also somewhat, in different individuals. For motor impulses, the conveyance through the spinal cord is also more rapid, by two or three metres per second, on the left side than on the right.

The time required to take the *first step in self-defence, when a pistol is fired at one's ear,* is *about* 1-5*th of a second;* thus the

Mechanism of hearing, & conveyance of sensory impression would require about	0.01″
Perception, & act of volition	0.10″
Transmission of motor impulse through spinal cord	0.04″
„ „ „ „ motor nerves	0.04″
Muscular contraction	0.01″
Total	0.20″

Thus *the brain* alone takes *as long to act as all the other parts together;* the time it requires, differs, however, very considerably in different individuals.

In the frog, the rate of conduction of *motor impulses* averages 25 *metres per second* (Helmholtz): – The data for the calculation were obtained by irritating a nerve at different points, and noting the moment of the occurrence of the corresponding contraction. – The rate of conduction appears to be somewhat greater in the peripheral than in the central parts; it diminishes a little when the temperature is lowered.

THE GANGLIA of the BASE of the BRAIN.

Form on the one hand the "*Sensorium Commune*," and, on the other, both the *motor centre called into play in all sensori-motor & emotional reflex actions*, and the *automatic agency which executes the mandates of the will.*

The "Sensorium Commune" – *i.e. The agency through which the mind is made conscious of all sensory impressions*, whether derived from the outer world or from the body generally through the "*Nerves of the External Senses*," or from the inner world, *i.e.*, the cerebral convolutions, through the "*Nerves of the Internal Senses*" (Reil).

After removal of the cerebral hemispheres the mental operations are no longer performed, and all emotional conditions are impossible; but sensation & motor power persist : – A brainless pigeon maintains its standing posture, or rests securely on a perch. If pushed, it walks ; if laid on its back, it rises ; if thrown into the air, it flies. If food be placed in its beak, it swallows & digests it. It turns its head at any loud noise, avoids obstacles in its way, and watches a lighted candle moved before its eyes ; if hurt, it endeavours to escape. Its general attitude, however, when left to itself, is that of perfect indifference. It keeps its eyes closed and its head beneath its wing, and scarcely moves. It awakes for a moment, but shows no alarm, when a pistol is fired close to it. It seeks for nothing, not even for food : – *Sensation & motor power are there, but ideas & emotions are wanting, and the will is dormant.*

Experiments on the ganglia of the base of the brain are, as a rule, unsatisfactory, for it is almost impossible either to reach the ganglia without previously removing the hemispheres, or to irritate, divide, or remove them singly. The following statements are based, however, partly on experimental, and partly on anatomical & pathological data : –

The optic thalamus, which receives the termination of the sensory tract of the medulla oblongata, is mainly a sensory centre. The corpus striatum, which receives the termination of the motor tract, is mainly a motor centre. The corpora quadrigemina are the seat of vision.

As a sensory centre, the *optic thalamus* supplies the "guiding sensation" necessary for progression & for the maintenance of the standing posture : – When it is wounded the animal turns round & round in a circular manner (évolution de manège) the rotation being towards the injured side if the anterior part of the thalamus has been injured, towards the opposite side if the posterior part has been injured (Schiff). If the thalamus is removed, the animal falls to the opposite side. That the loss of the "guiding sensation" is the cause of the abnormal movements, or of the apparent paralysis, is shown by the fact that the same or very similar movements may be induced either by partial division of the crus cerebri, or by the mere blinding of an eye, or the division of one of the semicircular canals (Flourens).

Pathology supports this view : – Disease of or hæmorrage into the *corpus striatum* induces *motor paralysis of the opposite side of the body*, those muscles being more particularly affected, which, like those of the limbs, act independently of their fellows. Disease of or hæmorrhage into the *optic thalamus* induces paralysis usually *both sensory & motor*; sensory because the optic thalamus is a sensory centre ; motor because, being situated internally to the corpus striatum and upon the fibres passing from the latter to the medulla, it can hardly be seriously injured without affecting the corpus (Broadbent.) – The production, through irritation either of the corpus striatum or of the corresponding "afferent nerves of the internal senses" (white substance of the hemisphere), of the definite combined movements first described by Fritsch & Hitzig in connexion with irritation of the convolutions, shows that the corpus striatum is the motor centre for most of the movements of the body, and that it acts, not only in response to ordinary sensory impressions (sensori-motor reflex actions), but also in response to impressions derived from the cerebral convolutions (ideo-motor and emotional reflex actions) : – On irritating the deeper parts of the corpus striatum, the animal opens its mouth, and alternately thrusts out and retracts its tongue (Burdon Sanderson).

Division of one of the crura cerebri induces complete paralysis of the opposite side of the body, both sensory & motor. Partial division induces rotatory movement towards the opposite side, the diameter of the circle of movement being proportionate to the distance of the incision from the anterior edge of the Pons.

The *corpora quadrigemina* are the seat of vision, and, as such, they supply important guiding sensations. Partial or total removal of these bodies on one side induces respectively partial & temporary, or total & permanent blindness of the opposite eye, and also temporary weakness of the opposite side of the body, with a tendency to rotatory movement. Irritation of one of the corpora induces contraction of both pupils.

The Motor Centre called into Play in all Sensori-Motor & Emotional Reflex Actions. – Vide above.

The stimulus, which calls forth the reflex action, is conveyed to the sensory ganglia either by the ordinary afferent nerves, or by the afferent nerves of the internal senses (sensori-motor reflex actions ; ideo-motor & emotional reflex actions). The guiding sensation is derived from one or several of the former.

"It is when the Cerebrum is not in a state which renders it capable of receiving and acting upon "Sensorial impressions, that we find the independent reflex activity of the Sensory ganglia most strikingly "displayed. Thus in the Infant for some time after its birth, it is obvious to an attentive observer, that a "large part of its movements are directly prompted by sensations to which it can as yet attach no distinct "ideas, and that they do not proceed from that *purposive* impulse which is essential to render them volun-"tary. This is well seen in the efforts which it makes to find the nipple with its lips; being probably guided "thereto at first by the smell, but afterwards by the sight also; when the nipple has been found, the act of "suction is purely excito-motor. So in the Idiot, whose brain has never attained its normal development, the "influence of sensations in directly producing respondent movements is obvious to all who examine his actions "with discrimination. In the adult man, in whom the Intelligence and Will are fully developed, we "have comparatively little evidence of this independent reflex action of the sensory ganglia :—all those "automatic actions which are *immediately* necessary for the maintenance of his organic life, being provided for "by the excito-motor portion of the nervous apparatus, so that although sensation ordinarily accompanies most "of them, it is not essential to them; whilst those which are necessary to provide more *remotely* for his require-"ments, are for the most part committed to the guidance of his reason. For the impressions which have been "brought by the afferent nerves to his sensorium, and which have there produced sensations, do not in "general react at once upon the motor apparatus (as they do in those animals in which the sensory ganglia "are the highest of the nervous centres), but usually transmit their influence upwards to the cerebrum, "through whose instrumentality they give rise to ideas and reasoning processes, which operate upon the "motor apparatus either emotionally or volitionally. And it is for the most part only when this upward "transmission is checked, either by the non-development or the functional inactivity of the cerebrum, or by "its complete occupation in some other train of action,—or, on the other hand, when the reflex action of the "sensory ganglia is called into play with unusual potency,—that we have any manifestations of the *sensori-"motor* or *consensual* mode of operation in Man, that are at all comparable in variety or importance to those "instinctive acts which are so remarkable in the lower animals (Carpenter)." Still examples of these classes reflex actions are furnished by the closure of the eye to a dazzling light, the involuntary laughter excited by tickling (sensori-motor reflex actions) ; the vomiting caused by the *remembrance* of some loathsome object, the convulsive movements produced, in hydrophobia, by the mere sight, sound, or *thought* of water (ideo-motor reflex actions) ; the start caused by a sudden fright, the picturing of the passions on the countenance (emotional reflex actions).

The Automatic Agency which Executes the Mandates of the Will – Vide Automatic Action.

FUNCTIONS of the CEREBRAL HEMISPHERES.

THE ELECTRICAL EXCITABILITY of the HEMISPHERES — Discovered by Fritsch & Hitzig in 1870, has already allowed of the recognition not only of "*Motor Centres*" (Fritsch & Hitzig, Ferrier), but also of "*Sensory*" & "*Instinctive*" *Centres* (Ferrier).

Motor Centres — "A new epoch in cerebral physiology was opened by the researches of G. Fritsch "and E. Hitzig. They exposed the brain in dogs, and applied as irritant to different "parts of its surface a continuous galvanic current of slight intensity. They found that no effect "followed the application of the irritant to the greater part of the surface of the hemispheres, "but that some parts were excitable, and that when these were irritated, well defined muscular "movements on the opposite side of the body occurred.

"The results of a further examination of the muscular centres in the brain of a monkey "showed that they were all situated between the great longitudinal fissure and the fissure of "Sylvius in the 'anterior central convolution,' (ascending frontal), the other parts of the hemi-"spheres being unexcitable.—Hitzig thinks that in man the parietal region is the excitable part.— "Nearest to the longitudinal fissure lies the centre for the posterior limbs, more externally that "for the anterior limbs, further down the facial centre, and, near the Sylvian fissure, the centres for "the mouth, tongue, and jaws; that for the eye muscles coincides with the upper part of the centre "for the muscles of the face. It is very important to observe that the centres for the mouth and "tongue are placed in the position of what is supposed to be the speech centre in man, and further "that all the movements grouped about this centre are bilateral, the corresponding muscles on "both sides being called into action by the irritation of one hemisphere."

"The most extended and valuable set of experiments yet made on the localisation of cere-"bral functions is that of Dr. Ferrier. The brain was laid bare, not all at once, but in detail; and, "after the removal of the dura mater, which all experimenters have found to be extremely sensitive, "the surface of the brain was irritated by induction currents from Du Bois Reymond's coil, the inten-"sity being in general slight, but varying according to the varying excitability of the parts "of the brain."

"The first effect of the application of the electrodes was to cause a condition of hyperæmia "of the parts acted on. This, Dr. Ferrier calls 'functional hyperæmia,' and he thinks that his "method of experimenting, by causing this, reproduces the normal functional activity of the "different parts of the brain."

"In the brains of cats, dogs, and rabbits, very well defined centres of movement were made "out. In the convolution bordering the great longitudinal fissure are the centres for the limbs, "paws, and tail. In the middle external convolution are those for the eyes, eyelids, and face; while "the inferior and Sylvian gyri contain the centres for the movement of the whiskers, angles of the "mouth, depressors of the jaws and tongue. According to the habits of the animal, certain cen-"tres are more highly and distinctly differentiated, as that for the tail in dogs, the paws in cats, "the mouth in rabbits. All the movements produced are 'purposive or expressional in character, "and such as we should attribute to ideation and volition.' This, and 'the intimate relation sub-"sisting between ideation and the unconscious outward expression of the idea in muscular action,' "Dr. Ferrier inclines to regard as 'strong proof of the close local association of the ideational and "voluntary motor centres.' 'Hence,' he says, 'I would incline to the opinion that the organic "centres of word memory are situated in the same convolutions as the centres which preside "over the muscles concerned in articulation' (Broca's convolutions). 'If this be so, then we "ought to have a hand memory, a face and eye memory, an ear memory, and thus we may ulti-"mately be enabled to translate into their psychological signification, and localize phrenologically, "the organic centres of various mental endowments.'"

"These researches were undertaken for the purpose of examining experimentally the views "of Dr. Hughlings Jackson on the Pathology of Epilepsy, and they led to an endeavour to deter-"mine the localization of the functions of the brain, not only as regards motion, but also *sensa-"tion* and other *mental faculties*." (From Dr. Purser's Report on Physiology in 'Irish Hospital Gazette,' *January*, 1875).

Sensory Centres — "In monkeys, Dr. Ferrier has been able to localize several regions whose function is "the perception of the impressions of the special senses. Thus, irritation of the angular gyrus "caused certain movements of the eyeballs and pupils. Destruction of this gyrus gave data for "regarding it as the cerebral expansion of the optic nerves, and the seat of visual perception. "Irritation of the superior temporo-sphenoidal convolution caused pricking of the ears, and "other indications of excitation of ideas of sound; it is probably the cerebral termination of the "auditory nerves. The sense of smell appears to be seated in the uncinate convolution. The "senses of touch and taste could not be localized with certainty, although indications of their "position were gained." (From same source).

Instinctive Centres — "In monkeys, the antero-frontal part of the brain, with the inferior frontal "and orbital convolutions, gave no definite result on stimulation. Extirpation caused a condition "like dementia. The occipital lobes did not react. Their destruction caused no loss of sensation "or motion, but abolition of the instincts of self preservation. It thus appears that 'those centres "of movement which may be regarded as giving expression to mental states that man shares "with animals beneath him, are all located in the *hinder part of the anterior lobes*, and the *anterior "portion of the middle lobes*, the part of man's cerebrum which corresponds with the entire cere-brum of the lower mammalia.'" (From same source).

SIGNIFICANCE of the FOREGOING RESULTS.

They are due to *irritation of the several "centres," not to conduction of the electric current to the ganglia of the base of the brain.* This is proved by the non-excitability of a very large portion of the convolutions, the insula included, which is nearer to the sensori-motor ganglia than any other portion of the cortex; by the different effects produced by stimulation of closely adjacent parts; by the absence of results in complete anæsthesia, though the corpora striata still remain excitable; by the low intensity of the currents used, and the close approximation of the electrodes; and finally by the fact, established by Burdon Sanderson, that when the grey matter of the several "centres" is removed, the same actions are still produced by irritation of the medullary fibres ("afferent nerves of the internal senses") which proceed from these centres to the corpus striatum.

"Hermann, though admitting the fact of definite movements being excited by local-"ised stimulation of certain cortical regions, denies that this proves the existence of motor "centres in the hemispheres, and grounds his opinion on the fact that dogs recover perfectly "from the effects of destruction of the so-called motor centres of the limbs, and regain com-"plete control of their movements."

"Fritsch and Hitzig are of opinion that these centres are in some way related to the "muscular sense on the ground that after the ablation of the limb-centres in dogs, the animals "so operated on do not suffer from paralysis of the limbs, but merely appear to have lost con-"sciousness of the position of the limbs, and hence place them in irregular and unnatural "attitudes. This view is also supported by Nothnagel from the results of his experiments "in the injection of chromic acid into the brain cortex."

"The interpretation which Ferrier puts upon his experiments differs essentially from "any of the foregoing. He regards the movements which result from stimulation, as indi-"cations of excitation of centres concerned in voluntary or purposive action, or of centres of "expression and sensation." (H. Power).

Burdon Sanderson states that "by exciting certain spots on the surface of the brain "a complicated series of changes originate more or less analagous to a psychical process."

The two latter views harmonise with what has been said of the mechanism of psychical action, and are supported by Ferrier's "functional hyperæmia."

THE CEREBRAL CONVOLUTIONS

Are the *necessary agents of perception & thought*, but they are *not the seat of consciousness.*

The *mechanism of psychical operations* is as follows :

1. – Impressions derived from a sensory surface and conveyed by the "*afferent nerves of the external senses*" (ordinary sensory nerves) to the ganglia of the base of the brain, give rise in these ganglia to *sensations.* *

2. – Sensations conveyed by the "*efferent nerves of the internal senses*" to the cerebral convolutions, give rise in those convolutions to *perceptions,* * by the combination of which perceptions, ideas, or intellectual representations of objects, are formed. – Simple perception probably takes place in the marginal convolutions, which are more directly connected with the sensori-motor ganglia; ideas probably originate in the central convolutions, which are less immediately connected with the sensori-motor ganglia, but which are connected with the foregoing convolutions by numerous arcuate or gyral fibres (Bastian).

3. – Ideas, returned by the "*afferent nerves of the internal senses*" to the ganglia of the base of the brain, give rise in these ganglia to *emotions & to acts of volition.*

4. – The mandates of the will are finally shaped into motor impulses in the motor ganglia.

That the cerebral convolutions are *not the seat of consciousness* is proved by the phenomena of "*Unconscious Cerebration*" & *remembered sensations :* – We are not directly conscious, on the one hand, of the changes which take place in the material substrata of our intellect (Vide "Unconscious Cerebration"), and, on the other, a remembered sensation is so completely the reproduction of the original, that the seat of the two cannot well be different. The seat of the former was in the ganglia of the base of the brain; these ganglia, therefore, and not the convolutions, are the seat of that which is reproduced by the cerebral act (Carpenter).

The cerebral convolutions are *not* therefore *an essential part of the nervous system.* They are merely a superstructure subservient to *Intelligence.*

* A *sensation* is the consciousness of an impression; a *perception* is the reference of a sensation to something outside the *ego.*

THE FACULTY of ARTICULATE LANGUAGE

Appears to reside in the *third or inferior frontal convolution of the left side* (Broca), which convolution would contain both the centre for the memory of words and the centre for the co-ordination or combination of the movements of speech.

Either centre may be affected separately.

If the *centre for the memory of words* be affected, the case is one of *amnesia* or *amnesic aphasia* :– The patient cannot *recollect* the word he wants, and can therefore neither pronounce it nor write it. But if it be pronounced before him, he recognises it at once and can immediately repeat it; though a moment afterwards it has again escaped him.

If the centre for the co-ordination of the movements of speech be affected, the case is one of *ataxic aphasia :* – The patient *knows the word* he wants, and can write it and recognise it when he hears it pronounced; but he *cannot pronounce it* himself, though he suffers from no loss of motor power in the tongue, lips, palate, or larynx.

Lesions of the intellect, or of the motor apparatus, either of phonation or of articulation, or of both *(alalia)*, may complicate individual cases.

The dependence of aphasia upon lesion of the *left* inferior frontal convolution—(it is generally due to cerebral hæmorrhage, and accompanied by right hemiplegia)—appears to result from the *greater or sole education of the left hemisphere of the brain* (Moxon), which hemisphere is usually larger and earlier developed than the other (Gratiolet). In left handed persons, aphasia and *left hemiplegia* have been found associated with *right* cerebral hæmorrhage. – Under deep emotion, aphasic patients may utter a few words, or even sometimes a whole phrase (Hughlings Jackson), the less educated hemisphere probably acting for the other one.

"The cerebral centres for bilaterally-acting muscles appear to be co-ordinated, so that "one centre can fulfil the offices of both. This view, put forward some years ago by Dr. "Broadbent, is adopted by Dr. Ferrier, but he thinks that his own experiments indicate, not "an *anatomical* but a *physiological* co-ordination through the media of the lower ganglia."

"These considerations will explain why it is that in destruction of the mouth and "tongue centre on one side there may be no paralysis of these parts. But the question arises, "why destruction of this centre in men, if it occur on the *right* side, causes no effect, while "if it occur on the *left* side, loss of speech results. The reason of this appears to "be that most persons are '*left brained;*' that is, that although a speech centre exists at "both sides, yet that the left is the driving side, and has an undue preponderance in initia- "ting voluntary movements. Just as the hand centre on the left side of the brain has been "educated to give the right hand its superior dexterity, so the speech centre in the left side has "been educated to initiate the voluntary recalling of words and the associating of them with "the ideas they express. The power of speech is lost just as the power of writing is lost in "the left-sided lesion of the brain, and as the patient can educate his left hand (right brain) "to write, so he can educate his right speech centre to remember words, and learn again to "talk. That such recovery of speech does not always occur depends very probably on the "fact pointed out by Vulpian that many persons with aphasia are also more or less demented. "(Dr. Purser, Irish Hospital Gazette)."

FUNCTIONS OF THE LOWER NERVE-CENTRES.

NOTE.

Two Tablets have been removed from this fascicle: "*Guiding Sensations*," or third Tablet on Reflex Action, and "*Kuss's Classification of Reflex Actions*." They will be found in the appendix. The note which preceded the latter Tablet is simply reproduced here :—

"KUSS'S CLASSIFICATION OF REFLEX ACTIONS was published at so nearly "the same date as my own and so much resembles it, that I have thought it desirable, for "the sake of comparison, to transcribe it *in extenso*. I may add that my first Tablet on the "subject was lithographed, and was widely circulated among Students in this country (*First* "*or Lithographed Edition of the Tablets on Physiology*, Renshaw, 1873) *nearly two years* before "Professor Küss's Classification, or any account thereof, appeared in the English language, "or became known to me. It is a singular coincidence that writers of two different countries "should develop essentially the same idea at so nearly the same time, and in terms so "nearly equivalent. It will be observed, however, that Professor Küss's "*Second Class*" "corresponds to my "*Third Class*," and *vice versa*.

T. C.

June, 1876."

FUNCTIONS of the NERVE-CENTRES in GENERAL

Are :—

Conduction – The cerebro-spinal nerve-centres are as perfect conductors as are the nerves. Not so with *the ganglia* of the sympathetic. These *impede transmission, and render it slow and imperfect:* none but intense & prolonged irritations are perceived through the nerves on which they are found, and none but intense and prolonged irritations are, through the instrumentality of these nerves, productive of motion. (Vide Sympathetic Nerve).

Transference* – Is that modification of the conduction of sensory impressions through the nerve-centres, by which modification an impression is perceived, generally more or less altered, and *as if it were derived from a point different from that from which it really was derived.* Common instances of transference are the painful sensation experienced at or near the end of the penis when the bladder is distended with urine, or when its walls are irritated by a calculus; the pain so commonly felt in the knee in hip-joint disease; the tickling perceived in the glottis when any part of the respiratory tract is irritated. In these cases the primary impression is conveyed to the cord or to the medulla oblongata by the afferent nerves of the irritated part, and is there transferred to the central ends of another set of nerve-fibres, by which it is conducted to the sensorium. It is there perceived as if it had originated in the area of distribution of these latter nerve-fibres.

Diffusion or Radiation* – Is that other modification of the conduction of sensory impressions through the nerve-centres, by which modification an impression conveyed to a nerve-centre by one nerve only, is perceived *as if it had been conveyed by several, and as if it had been derived from an area much more extensive than that of the real primary impression.* The pain of a calculus in the ureter spreads far & wide; the aching of a caried tooth may extend to the adjoining sound ones, and may, independently of any morbid condition of the central part of the 5th nerve, be accompanied by violent & extensive neuralgia of the face.

Reflex Action – Vide two following Tablets.

* These descriptions are now somewhat antiquated, and will probably be removed from the next issue of the Tablets.

REFLEX ACTION.—1st Tablet.

What is generally understood by "reflex action" is *the production of a motor impulse in a nerve-centre, and the conveyance of this impulse from the nerve-centre to a muscle or a series of mucles in consequence of the reception by the said nerve-centre of a sensory impression conveyed to it by a centripetal nerve;*— of the reception of which impression the mind may or may not be conscious, or may be conscious to a very variable extent.

For the production of a reflex action *three conditions* are necessary: –

1. – *The continuity of the centripetal nerve* between the irritated point and the nerve-centre.
2. – *The uninjured state of the nerve-centre.*
3. – *The continuity of the centrifugal nerve* from the nerve-centre to the muscle or muscles. — Nothing more is requisite.

Hundreds of reflex actions are constantly taking place within the animal frame. They are all purposive, and adapted, at least in health, to secure some desirable end.

Taking the visceral branches of the pneumogastric to be derived from the ganglia of that nerve, and to be similar, or at least comparable, to the sympathetic nerves, these numerous reflex actions may be correctly and conveniently divided, the Author believes, into four classes according to the channels through which, in each individual case, the sensory impression & the motor impulse are conveyed. The sensory impression & the motor impulse may be conveyed respectively by: –

1st Class – *Two cerebro-spinal nerves;*
2nd Class – *A sympathetic or ganglionic nerve & a cerebro-spinal nerve;*
3rd Class – *A cerebro-spinal nerve & a sympathetic or ganglionic nerve;*
4th Class – *Two sympathetic or ganglionic nerves.*

These classes, in well marked examples, differ considerably in general outline.

The Reflex actions of the FIRST CLASS *highly resemble volitional acts.* In man they are, in fact, but artificial or acquired reflex actions (Huxley), actions, which, to be rightly performed, required at first the exercise of both attention & will, but which, by frequent repetition, are subsequently performed with less & less intellectual guidance, till they are at last accomplished, so to speak, mechanically, and without the mind being conscious, or wholly conscious, when several of them are simultaneously performed, of their separate & individual performance. *They can be controlled by the will when the mind is watchful & on the look-out.* They are often most complex, but are nevertheless performed with remarkable precision, and, when it is required, with astonishing rapidity. – Ex.: *Outstretching of the arms when the body is falling; movements of the limbs in walking or running; movements of the fingers in playing a musical instrument, &c.*

Those of the SECOND CLASS form part of several of the thoraco-abdominal functions. They partake to a less extent of the character of volitional acts. *The will can control them to a certain extent only.* They are never so rapid, nor, though they are often very extensive, are they ever so complex as are some of those of the first class. – Ex.: *Muscular contractions in breathing, coughing, vomiting, &c.*

Those of the THIRD CLASS are the non-visceral vaso-motor reflex actions, which govern the nutrition & the secretions of the body generally. *The will has no power over them, though the mind may take cognizance to a considerable extent of the impressions to which they are due:* – Ex.: *Contraction & dilatation of the capillaries under the respective influences of cold & heat, secretion of tears after the irritation of the conjunctiva, &c.*

Those of the FOURTH CLASS are the reflex actions of the thoraco-abdominal viscera, and the vaso-motor reflex actions which govern the nutrition & the secretions of the latter. *The will has no power over them, and the mind takes no cognizance of their occurrence, except sometimes in cases of disease.* – Ex: *Peristaltic action of the intestine, secretion of gastric juice, &c.* – (Vide Functions of the Sympathetic).

Reflex actions may be further divided, *with regard to the mode and point of origin of the motor impulse,* into *Excito-motor, Sensori-motor, & Emotional* (Carpenter): –

When the spinal cord is separated from the sensorium, either *structurally,* – through division or injury, – or *functionally,* – the activity of the latter being either engaged in another direction, or being temporarily suspended, as in profound sleep, – the exciting impression, arrested in its course towards the brain, reacts upon the motor centres of the cord or medulla; and the reflex action induced *independently of sensation,* is termed Excito-Motor. Such reflex actions are governed by the laws of Pflüger (Vide Reflex Action of the Spinal Cord). The reflex actions of the *second, third, & fourth classes* belong more or less to this category.

Should the mind be intent upon impressions derived from another source, the supervening impression, though it be conveyed to the sensorium, may still *not* be, *or* may be *but imperfectly perceived;* – the sensori-motor ganglia reacting in this case, so to speak, automatically, or of their own accord, the reflex action induced may be called Sensori-Motor or Consensual: – Such are the ordinary ambulatory movements of the limbs. And, in general, all movements which have been habitually performed in a particular sequence, may be kept up, when the will has once set them *en train,* through the automatic agency alone, the impression or sensational change produced by each action supplying the stimulus which calls forth the next.

Finally, the impression may be *perceived* in the sensorium, *and conveyed to the hemispheres.* It is here transformed into an *idea;* and the idea, when returned to the sensorium, there gives rise to an *emotion.* The responding movement, which, if, from any cause, the action of the Will be either suspended or weakened, is still essentially reflex in nature, is now termed Emotional or Ideo-Motor.

REFLEX ACTION.—2nd Tablet.

AUTOMATIC ACTION.

The production of the motor impulse is considered by several german physiologists as the mere letting loose, by means of a so-called *liberating* or *discharging force*, of previously accumulated *potential, i.e.*, counterbalanced or neutralised, *energy;* which potential energy would thus be transformed into *kinetic, i.e.*, active or efficient, energy; and upon this assumption is based the division of the activitics of the nerve-centres into *Reflex proper* & *Automatic*.

Automatic action, as opposed to reflex action proper, would be characterised, as regards its causation, by its originating in the *absence of any external influence*, and, as regards the action itself, by its being either *continuous*,—muscular tonus,—or *rhythmical*,—respiratory movements, action of the heart.

And here comes in the theory of "*inhibition*" in explanation of the rhythmical character of certain automatic actions: – A certain resistance has to be overcome before the automatic action can be induced. Hence the liberated energy has to acquire a certain tension before it can act as an efficient stimulus; and any force which would hinder ('inhibit') the automatic action, *i.e.*, increase the resistance thereto, would, on the one hand, slacken its rhythm, and, on the other, proportionately increase its energy.—"Certain phenomena, "especially the action of some fibres of the vagus of the heart, can only be explained in a very forced manner "by other theories. If it be established as a certainty that the influence of these fibres upon the central "organs merely consists in a modifying action exerted by them upon the organs in question, of such a nature "that the activities of the latter are differently distributed *as to time*, and hence that the strength "of every "discharge of energy is inversely proportional to its frequency, it can only be explained by assuming that "the hypothetical resistance is increased by the activity of certain fibres (inhibitory fibres) and diminished "by the activity of others (accelerating fibres)." (Hermann).

With regard, however, to the MECHANISM OF THEIR PRODUCTION, *all reflex actions, and even all 'voluntary' actions, are essentially automatic;* the power of the will or the reflex influence of a sensory impression being limited in every case to the setting in motion of a self-acting apparatus, which, when once called into play, will, of itself, either comply with the requirements of the organism, or execute the mandates of the will. The will, in fact, in no wise exercises that direct control over the 'voluntary' movements, which ordinary phraseology would seem to imply. Its influence is directed towards the *result* of muscular action, not towards the singling out of the individual contractions in their necessary combination & sequence. "If it were "otherwise, we should be dependent upon anatomical knowledge for our power of performing the simplest "movements of the body; whereas we find the fact to be, that the man who has not the least idea of the "mechanism of muscular action, can acquire as complete a command over his movements, and can adapt "them as perfectly to the desired end, as the most accomplished anatomist could do. Further, we cannot, "by any exertion of the will, single-out a particular muscle, and throw it into contraction by itself, unless "that muscle be one which is alone concerned in an action that we can voluntarily perform; and even then "we single it out by willing *the action*. Thus we can put the *levator palpebræ* in action by itself; but "this we do, not by any conscious determination of power to the muscle itself, but by willing to *raise the "eyelids*." (Carpenter).

The only essential difference between voluntary & involuntary movements lies therefore in the *origin* of the stimulus which calls the automatic agency into play. And even this difference is more apparent than real, as is shown by that gradual conversion of volitional into involuntary & even unconscious action, which conversion gives rise to the '*reflex actions of the first class*.' The nervous system 'grows to' the mode of action in which it is habitually called into play, the same kind of connection between the sensory and motor nerves being established by a process of gradual development, as that which was original or innate. "Whilst "special tracts are originally marked out for the automatic (primarily automatic) movements, others may "be gradually worn-in, so to speak, by the habitual action of the Will; and thus, when a train of sequential "actions primarily directed by the Will has been once set in operation, it may continue without any further "influence from that source. . . . It is whilst the organism is growing most rapidly, and the greatest "amount of new tissue is consequently being formed, that the assimilative processes most readily take on "that new mode of action, which often becomes so completely a 'second nature,' as to keep up a certain "acquired mode of nutrition through the whole subsequent life. Habits are far more readily acquired "during the periods of infancy, childhood, and youth, than they are after the attainment of adult age; and "the earlier they are acquired, the more tenaciously are they retained." (Carpenter).

Furthermore the response of the CEREBRUM itself is often as essentially reflex or automatic as is that of the muscles. To individual peculiarities in the mode of action (and probably also in the acquired construction) of the nerve-centres are due the individual peculiarities of character. And these are, though doubtless to a variable extent, on the one hand inherited, on the other hand acquired, – the natural & unrestrained response of the cerebrum being, in every case, both as regards mental action & emotional conditions, the resultant in each individual of the promptings of the congenital constitution, modified by the effects of early training. "If any two mental states be called up together, or in succession, with due "frequency and vividness, the subsequent production of one of them will suffice to call up the other, and "that whether we desire it or not." (Huxley).

The reflex activity is greatest in *young animals*, and greater in *birds* than in mammals, in *mammals* than in fishes. It is *exalted* by strychnia, opium, alcohol, nicotine, partial interruption of the blood-supply. It is *enfeebled* by chloral hydrate, belladonna, bromide of potassium, exhaustion of the nerve-centres. The more powerful the stimulus, the more rapidly the reflex action takes place. A reflex action is induced earlier on the irritated side of the body, than on the other side.

FUNCTIONS of the SPINAL CORD.—1st Tablet.

EXCITABILITY.

It is a debated point whether the spinal cord is directly excitable by any of the artificial stimuli that we can experimentally apply to it, as it was still said to be a few years ago, in acordance with the doctrines of Sir C. Bell & Longet. – According to *Brown-Séquard,* the stimuli, which, when applied to the anterior & posterior roots of the spinal nerves, give rise, in the one case, to muscular contractions, and, in the other, to pain, do not, except in the case of the electric stimulus, give rise to any such effects when carefully applied to the surface of the cord, even the exception in the case of the electric stimulus only occurring when the current used is a strong one, and when the cord is irritated in the vicinity of the roots of the nerves; in such cases *the irritation extends to the internal or deep part of the roots of the nerves,* and it is through the agency of these roots, just as when they are irritated at some distance from the cord, that either pain is produced, or muscular contractions take place. *The proper or commissural fibres of the cord are totally unexcitable.* – According to *Vulpian,* the posterior columns & the adjacent part of the lateral columns are sensitive, and the anterior columns & the adjacent part of the lateral columns are somewhat excitable (motor), the sensibility of the former and the excitability of the latter being most marked towards the surface and in the vicinity of the roots of the nerves, but not being entirely due, however, to the instrumentality of these roots: – The posterior columns, after being divided transversely and separated from the adjoining parts for a distance of several centimetres, still show signs of sensibility; upon the posterior & lateral columns, with the anterior and posterior roots, being removed for a distance of several centimetres, the anterior columns & the grey matter alone being left, these anterior columns are still found to be excitable.

Remarks. – The *posterior columns have probably no sensibility of their own*; Vulpian's experiment does not prove the contrary, for it has been shown that in some parts of the cord, in the lumbar portion in particular, the posterior roots run upwards for at least two or three inches before they enter the grey substance. It is probable, therefore, that the proper fibres of these columns are mainly commissural, and, that *they merely connect the different segments of the grey matter, and aid in the co-ordination of the more complex movements:* – Their degeneration induces locomotor ataxy; and if they are divided transversely in several places, the movements of locomotion become more and more incoordinate in proportion to the number of transverse sections. Vulpian is probably right, however, in saying that, *independently of their roots, the anterior columns are somewhat excitable.* They are *also slightly sensitive,* as are the anterior roots; their sensibility being doubtless due to the prolongation backwards towards the cord of those recurrent sensory fibres which the anterior roots derive from the posterior ones.

It is generally agreed that the *grey substance* of the cord is both *unexcitable and destitute of sensibility.*

FUNCTIONS of the SPINAL CORD.—2nd Tablet.

CONDUCTION.

It was believed up till lately, also in accordance with the doctrines of Sir C. Bell & Longet, that the antero-lateral & posterior columns of the cord were, at least functionally, the continuation of the corresponding roots of the nerves, and that, as these roots are conductors of motor impulses & sensory impressions respectively, so were also the latter. This belief was based partly upon the mistaken notion that the tracts of the cord were directly excitable, and that they responded, as do the roots of the nerves, to the stimuli applied to them; and also partly upon the results of the following rough experiment: – The cord was cut through horizontally and electric stimuli were applied to the cut surfaces of the segments. *Muscular contractions* were then seen to take place when the stimulus was applied to the *cut surface of the caudal portion of the antero-lateral column*, while *pain* was manifested when the stimulus was applied to the *cut surface of the cephalic portion of the posterior column.* – In this experiment both the muscular contractions produced and the pain elicited, were due, not, as was presumed, to irritation of the proper fibres of the cord, but to *irritation of the internal or deep part of the roots of the nerves* as they ascend or descend between the white fibres of the cord to join the cells of the grey matter. The conclusion was therefore groundless.

The correct statement of facts is as follows: –

Sensory Impressions:

I. – *Pass for a short distance upwards & downwards through the white substance, along the fibres of the internal or deep part of the posterior roots, as is shown by:*

Transverse section of *posterior half* of cord: –	After the operation *signs of pain* are elicited by *irritation*, on *either surface of section*, of the internal or deep part of the posterior roots, as they ascend and descend respectively in the cephalic & caudal segments of the cord. *

II. – *Cross over entirely (Brown-Séquard), almost entirely (Vulpian), into the opposite side of the cord, as is shown by:*

Transverse section of one *lateral half* of cord: –	*Sensation totally lost*, or greatly impaired, in *opposite side* of body, slightly impaired, perhaps, on side of section.
Median section down the cord: –	*Sensation totally lost*, or greatly impaired, on *both sides*.

III. – *Ascend to the cerebrum through the grey matter, as is shown by:*

Transverse section of both *antero-lateral & posterior columns*, the grey matter alone being left uninjured: –.	*Sensation unimpaired*, or but slightly impaired, on either side.
Transverse section of *antero-lateral columns & grey matter*, posterior columns alone remaining uninjured; *or* of *posterior columns & grey matter*, antero-lateral columns alone remaining uninjured:	*Sensation totally lost on both sides.*

It may be added that partial destruction of the grey matter impairs the sensibility in all the parts below, but does not destroy or diminish it in any one part in particular; and that sensibility is never entirely lost so long as any of the grey matter remains uninjured.

* An additional remarkable result of this experiment is the *increased sensibility of all the parts below*, which is observable a few hours after the operation, and which persists to a greater or less extent for several days or weeks; it is probably due to the congestion of the cord in consequence of the suppressed action of the vaso-motor nerves. Division of one lateral half of the cord similarly affects the corresponding half of the body.

Motor Impulses:

I. – *Descend from the cerebrum through those fibres of the mesocephalon & medulla oblongata which are continuous with the opposite antero-lateral column of the cord, as is shown by:*

Disease of, or *injury* to, *one side of the cerebrum*, or *division* of one of the *crura cerebri or* of one of the *anterior pyramids above the decussation*: –	*Motor power totally lost*, or very greatly impaired, usually in limbs of *opposite side*, & in opposite half of body.

II. – *Pass to a great extent into the opposite side of the cord at the point of decussation of the anterior pyramids, as is shown by:*

Transverse section of *one lateral half* of cord *below point of decussation* of anterior pyramids: –	*Motor power totally lost*, or very greatly impaired, in limbs of *same side*, & in corresponding half of body.
Median section through point of decussation: –	*Motor power totally lost*, or very greatly impaired, *in all the parts below.*

III. – *Descend through the antero-lateral column & perhaps also through the adjoining part of the grey substance, as is shown by:*

Transverse section of *antero-lateral colum*: –	*Motor power totally lost*, or very greatly impaired, *in all the parts below.* †
Transverse section of *posterior columns & grey matter* (the grey matter cannot be divided alone: –	*Motor power slightly impaired in all the parts below.*
Median section down the cord; –	*Motor power unimpaired* on either side.

It must be added that some of the fibres of the anterior roots decussate throughout the whole or nearly the whole of the cord; these fibres are probably concerned in the conveyance, not of voluntary, but merely of reflex impulses (Brown-Séquard).

† In the cervical region division of the *lateral* column alone produces a greater amount of paralysis than division of the anterior column alone; in the dorsal & lumbar regions, division of the *anterior* column alone produces a greater amount of paralysis than the division of the lateral column alone.

FUNCTIONS of the SPINAL CORD.—3rd Tablet.

SPECIAL SENSORY & MOTOR CHANNELS.

Appear to be devoted to the conveyance of the impressions of *pain*, *temperature*, *touch & tickling*, & the *muscular sense*, and to the conveyance of the *involuntary motor impulses of epilepsy* (Brown-Séquard).—The conductors of impressions of *pain* are disseminated throughout the posterior & lateral parts of the grey substance. The conductors of impressions of *temperature* are found in the central parts of the same. The conductors of the impressions of *touch & tickling* lie mainly, according to some physiologists, in the anterior part of the grey substance. Schiff maintains, however, that they lie in the posterior white columns. The conductors of the *muscular sense*, appear to decussate in the medulla, not in the cord. The fibres which convey the *involuntary motor impulses of epilepsy* lie according to Brown-Séquard in the lateral white columns, and, in accordance with this supposition, Charcot has observed that Sclerosis of these columns is invariably accompanied by muscular spasms.

FUNCTIONS of the SPINAL CORD.—4th Tablet.

REFLEX ACTION.

Is excito-motor. The cord contains the *vesical, anal, & genital centres,* and, with the medulla, it governs the *calibre of the blood-vessels* (Vide Vaso-motor reflex action & sympathetic nerves), and maintains the *muscular tonus* throughout the body.

The reflex power of the cord *increases when the cord is severed from the cerebrum,* and, as successive transverse sections are made from before backwards, the reflex power of the gradually diminishing caudal segment progressively increases (Schiff). This can hardly be attributed to the suppression of any intra-cranial (Setschenow) or spinal (Nothnagel) inhibitory centres, and, in all probability, is simply due to the *increased excitability of the grey matter induced by local irritation* (Küss); any irritation of the cord induces hyperæsthesia, which condition must, a stimulus being given, increase the energy of the corresponding reflex action (Dalton). – This increased excitability might, it is true, be attributed, to *increased vascularity dependent upon increased vaso-motor, or suppressed vaso-inhibitory action.* This supposition would tally with the fact, which lies at the basis of Setschenow's & Nothnagel's hypothesis, *i.e.,* that irritation of the cerebral ganglia, the medulla, or the upper part of the spinal cord diminishes both the excitability & the vascularity of all the parts below; and it would, to a great extent, conciliate both opinions.

The *laws of Pflüger* govern the reflex actions of the first class both as regards the muscles called into play, and as regards the energy of their contraction; these laws are as follows: –

1. The *minimal impression* is reflected upon a *motor nerve of the same plane and same side of the body,* and upon the muscle or muscles it supplies.
2. A *stronger impression* is reflected, not only as above, but *also upon the corresponding nerves & muscles of the opposite side,* these latter muscles contracting less vigorously than, or at most as vigorously as, those of the side irritated.
3. An *impression somewhat stronger* is reflected upon the *nerves above, either of the same side of the body or of both sides,* – never upon the nerves below.
4. An *impression stronger still reaches the medulla oblongata,* is reflected upon *all the motor nerves of the body,* and gives rise to *general convulsions.*

As far as the reflex actions of the first class are concerned, *the power of the cord, when isolated from the cerebrum, is relatively slight in man & in the warm-blooded animals generally.* In both cases the decapitated body rolls over into any fortuitous position which its weight and the resistance of surrounding objects may combine to give it, and the movements of the parts irritated are disorderly and apparently purposeless. *A brainless frog,* on the contrary, *maintains very nearly its normal attitude;* if a limb be irritated, it is withdrawn towards the body, if a drop of acid be placed on the inner condyle of the femur, the animal will wipe it away, using either the foot of the same side, or, if it be prevented from doing this, using, after a moment's hesitation, the foot of the opposite side.

That these phenomena are due, not to any psychical action, but simply to the reflex activity of the spinal cord, is shown by the great uniformity of the movements in question, and by the absence of all spontaneous action in the part of the decapitated trunk. The lower an animal is placed in the scale of beings, the more its actions are governed by the pre-arranged mechanism of its nerve-centre, and the less is left to voluntary choice; the more, therefore, of those movements which appear to be purposive, can be performed under the sole influence of the cord.

The *vesical, anal, & genital centres* lie in the *lumbar portion* of the cord, and the normal movements of the pelvic organs may be induced by irritation either of these centres or of the nerves emanating from them.

The *anal centre* governs the reflex actions of the sphincter & levator ani and of the circular & longitudinal fibres of the gut; upon the rectum becoming distended, the sphincter relaxes (unless it be contracted voluntarily), and both the levator ani & the fibres of the gut contract, the former drawing upwards and opening the orifice, the latter expelling the fæces.– The power of the sphincter to resist defecation is overcome *(involuntary discharge)* when the distention of the gut increases beyond a certain limit, especially if the irritability of either the rectum or cord be increased by disease. The discharge though still remaining intermittent, becomes *both involuntary & unconscious* when the cord is injured above the anal centre. When the anal centre itself is destroyed the fæces are evacuated *as fast as they descend into the rectum,* the sphincter being paralysed.

The *vesical centre* governs the reflex contractions of the sphincter vesicæ and of the muscular coat of the bladder; – the reflex action of micturition is similar to that of defecation, and it is similarly affected by injury to the spinal cord.

The *genital centre* governs the phenomenon of *erection* both in the male and female, and the reflex contractions of the vesiculæ seminales, vasa deferentia, pregnant uterus & perinæal muscles. All the genital functions may be performed under the sole influence of this centre (Goltz & Frewsberg). – Erection consists in the *active dilatation of the arteries of the erectile organs,* and may be induced by irritation of the *nervi erigentes,* which arise from the above centre and traverse both the sacral & hypogastric plexuses (Eckhard).

FUNCTIONS of the MEDULLA OBLONGATA.—1st Tablet.

CONDUCTION — *The motor impulses decussate in the anterior pyramids;* and so do also the vaso-motor impulses (Schiff). *Sensory impressions,* those of the muscular sense excepted (Brown-Séquard), *do not decussate in the medulla;* they decussate in the cord below.

REFLEX OR AUTOMATIC ACTION — Governs:—

Mastication & Deglutition;
Phonation, Articulation, & Mimetic expression;
Respiration;
The action of the heart;
Vaso-motor reflex action;
The movements of the iris.

Mastication & Deglutition — That mastication & the *first act* of deglutition, though they are controllable by the will, are nevertheless of a somewhat *reflex, associated, or secondarily automatic* character, is shown, not only by their continuance, though the voluntary stimulus (the meal being once begun) be partly or wholly withdrawn, but also by their imperfect performance by the direct influence of the will, when the fifth nerve is paralysed. The *second & third acts* of deglutition are *completely automatic,* and as long as the medulla is entire or not seriously injured, they continue to be performed spontaneously when food is introduced into the back of the mouth. — The *afferent nerves* engaged in this reflex action are the inferior division of the fifth, the glosso-pharyngeal, & the superior laryngeal branch of the pneumogastric; the *motor nerves* are the motor root of the fifth, the facial, the pharyngeal & inferior laryngeal branches of the pneumogastric, & the hypoglossal.

Phonation, Articulation, & Mimetic Expression — These are also *associated or secondarily automatic actions,* and there are good reasons to believe (Van der Kolk, Duchenne, Lockhart Clarke) that their *centre* is in the *olivary nucleus.* — The stimuli for these reflex actions may be conveyed to the medulla through any sensory nerve, or may, in the shape of emotions, be handed down from the ganglia of the base of the brain:— A shriek, — unconscious & purely excito-motor in character, — is uttered, though the whole encephalon, excepting the medulla, be removed, when either the medulla is irritated or the foot is pinched (Vulpian).

The efferent nerves govern the laryngeal muscles (superior & inferior laryngeal branches of the pneumogastric), those of the tongue (hypoglossal), those of the face (portio dura of the 7th); — the *glosso-labio-laryngeal paralysis* is the expression of chronic degeneration of the grey matter of the medulla.

Respiratory Movements — Are sufficiently under the control of the will to render them *subservient to phonation & articulation,* but unrestrainable beyond these limits; therefore *essentially automatic, unaccompanied by fatigue, & usually unconscious.* The centre which governs them lies *in the interior of the medulla opposite or a little below the origin of the pneumogastric nerves;* and not only may the cerebrum, cerebellum, mesocephalon, and the spinal cord up to the origin of the phrenic nerves (and in birds & reptiles, which have no diaphragm, up to the medulla itself) be removed gradually without respiration ceasing, but even the exterior of the medulla may be shaved off to within a few lines of this part, and the animal will still continue to breathe.

The *chief afferent, sensory, or excitor nerve is the pneumogastric;* when both pneumogastrics are divided, the inspiratory movements become *much slower, though somewhat deeper* (Vide Pneumogastric Nerve). That *other nerves* also may convey the impression of the necessity of breathing is rendered evident, however, by the sudden gasping for breath produced by the dashing of cold water into the face, and by the deep inspiration preparatory (as the case may be) to sneezing, coughing, vomiting, or to the voiding of the urine or of the fæces, or to the expulsion of the fœtus, produced by irritation of the nasal fossæ, or of the lower part of the respiratory or upper part of the digestive tracts, or of the bladder, rectum, or uterus. The circulation of imperfectly aerated blood in the medulla oblongata itself may also act as a stimulus to respiration; an excess in the amount of carbonic acid in the blood stimulating the medulla more than a deficiency in the proportion of oxygen. The *most important efferent or motor nerve* is *the phrenic,* but almost all the nerves of the body may be considered to form part of the respiratory system of Sir C. Bell, for almost every muscle may be called into play in violent respiratory efforts: — *Division of the cord* in the *lower cervical region* paralyses the *intercostal muscles;* respiration is then continued by the diaphragm. Division *above the 3rd cervical vertebra,* paralyses the *diaphragm* also; suffocation then takes place rapidly, inspiratory efforts continuing, however, for a time in the muscles of the face, neck & larynx. As soon as the *respiratory centre* is *injured, respiration ceases immediately;* no further attempt whatever being made at inspiration, the stimulus for which is no longer perceived; as a consequence, the action of the heart is soon arrested. Division of the *medulla above the respiratory centre* interferes merely with the *inspiratory movements of the nostrils.*

FUNCTIONS of the MEDULLA OBLONGATA.—2nd Tablet.

Action of the Heart – The medulla oblongata contains *both the cardio-motor, & the vagal or extra-cardiac inhibitory centres* (Vide two following Tablets).

Vaso-Motor Reflex Action – The medulla oblongata contains *both the vaso-motor & the vaso-inhibitory centres;* the former extending in the rabbit from a little above the apex of the calamus scriptorius to a little below the tubercula quadrigemina (Ludwig & Owsjannikow),* and being, on the one hand, *in constant automatic action*, inducing *arterial tonus* and, on the other hand, *in reflex relation with afferent and efferent nerve-fibres*, which latter fibres decussate in the anterior pyramids (Brown-Séquard), descend along the antero-lateral columns of the spinal cord, issue through the anterior roots of the spinal nerves, and then run both along the spinal and along the sympathetic nerves, which latter nerves they join through the rami communicantes: – *If the vaso-motor centre be stimulated* by direct excitation of the medulla, by the venous condition of the blood, or by irritation of almost any sensory nerve, *or if the spinal cord or a vaso-motor nerve be stimulated*, and an artery be watched, *the artery will be seen to contract*, the stream of blood in its interior being first accelerated, then slackened, and finally perhaps arrested. *If the vaso-motor centre be destroyed, or if the cord below it or a vaso-motor nerve be divided, or if the vaso-inhibitory centre be stimulated through the depressor nerve*, and an artery be watched, *the artery will be seen to dilate;* – and, *if the area of vaso-motor action be extensive* (as when either of the two centres, or the spinal cord, or a commanding nerve, such as the depressor or one of the splanchnics, is brought into play), the *general arterial pressure* will be either considerably *elevated* or considerably *depressed*, and, in addition, the *action of the heart* will be, in the one case *slackened*, in the other case *accelerated.* †

The *course of the vaso-motor* nerves is somewhat complex: – Those of the *limbs* proceed from about the middle of the thoracic portion of the spinal cord, those of the *upper limb* ascending to the cords of the brachial plexus through the superior thoracic portion of the sympathetic, and those of the *lower limb* descending through the abdominal & pelvic portions of the same to join the anterior crural & sacral nerves. Division of the roots of the nerves of the limbs in the spinal canal does not affect the temperature of the limbs; the temperature of either limb is suddenly raised, however, by division of the cords of the corresponding plexus. – The vaso-motor nerves of the *head & neck* follow the cervical portion of the sympathetic. – Those of the *abdominal viscera* descend through the splanchnic nerves. – The vaso-motor fibres which run along the sympathetic nerves arise also in part from the sympathetic ganglia, as is shown by the influence of the submaxillary ganglion over the vascularity & secretion of the submaxillary gland (Vide Functions of the Sympathetic).

* In some animals the vaso-motor centre appears to be prolonged downwards into the *cord* (Brown-Séquard); in others it is prolonged upwards into the *mesocephalon* & the *crura cerebri* (Schiff).

† "Increased blood-pressure exerts a double action. On the one hand, it excites the heart to in-"creased frequency of action by direct irritation of its motor ganglia; on the other hand, it stimulates the "vagal centres in the Medulla, and thus causes slowing of the heart, the actual result in any given case "being dependent upon the preponderating influence of the cardiac motor or medullary inhibitory centres. "Usually the medullary centres are strongest, and increased blood-pressure causes slowing of the heart; "but if the vagi be divided, so that they can no longer act on the heart, increased blood-pressure stimu-"lates the heart to more rapid action." (H. Power).

Movements of the Iris – The dilatation of the iris is governed by the *two cilio-spinal centres* situated, the one in the *spinal cord* between the sixth cervical & second dorsal vertebræ, the other in the *medulla oblongata* close to the origin of the hypoglossal nerve (Budge). From these centres fibres ascend through the *cervical cord & the cavernous plexus of the sympathetic to the ciliary or lenticular ganglion*, from whence they pass to the eyeball to supply the *radiating fibres of the iris;* some fibres are said to pass through the Gasserian ganglion & the ophthalmic branch of the fifth nerve: – Irritation of either of these centres, or of the sympathetic in the neck, induces immediate dilatation of the pupil. – The cilio-spinal centres are stimulated by the venous condition of the blood, so that the pupils dilate in asphyxia. – The *circular fibres* of the iris are supplied by the *third nerve.*

INFLUENCE of the NERVOUS SYSTEM over the ACTION of the HEART.—1st Tablet.

The contractions of the heart are *not governed directly by the cerebro-spinal nerve-centres*, for injury to the latter amounting even to total destruction, does not, if gradually inflicted, stop the heart's action, and, if suddenly inflicted, generally occasions but a temporary interruption due to *shock*, especially if, in the case of warm-blooded animals, artificial respiration be resorted to. The action of the heart continues even after that organ has been completely disconnected from all other structures and removed from the body, and continues under such circumstances for several minutes in the case of warm-blooded, and for several hours in the case of cold-blooded animals.

The immediate cause of the heart's action lies, therefore, *within the heart itself, i.e., in the numerous ganglia & nerves of the sympathetic system*, which are distributed throughout the substance of the heart, and more particularly, in the frog, in the *ganglia of Remak*, situated near the opening of the inferior vena cava, and in the *ganglia of Bidder*, situated in the left auriculo-ventricular septum near the sinus venosus.

To these ganglia are added the *ganglia of Ludwig*, which are situated in the inter-auricular septum, & whose action upon the former appears to be *inhibitory*: – If these latter ganglia be irritated, the heart stops in diastole. If the heart be so divided that one part contain the ganglia of Remak, while the other part contains the ganglia of Bidder & Ludwig, the former part will continue to act while the latter will remain motionless; but if now the larger segment be again divided so as to separate the auricles containing the ganglia of Ludwig, from the ventricle containing the ganglia of Bidder, the latter will commence to beat, while the former will continue quiescent.

A treble influence is brought to bear upon the cardiac ganglia: –

1. – To the intra-cardiac inhibitory centre (Ganglia of Ludwig) is superadded the *vagal or extra-cardiac inhibitory centre* contained in the medulla, whose influence is conveyed to the heart through the *pneumogastric nerve and its cardio-inhibitory branch.*

2. – The cord of the sympathetic and the cardiac nerves which arise from its inferior cervical & first dorsal ganglia, convey from the *cardio-motor centre* contained in the medulla an influence which stimulates the heart, or perhaps merely modifies the distribution of its efforts in time in the direction of greater frequency of action counterbalanced by decreased energy.

3. – The *vaso-motor system*, while subjected by means of the *depressor nerve or vaso-inhibitory branch of the vagus* to influences originating in the heart, influences indirectly, on the other hand, both the vagal & the intra-cardiac inhibitory centres.

Certain poisons, also, have a well-marked influence both over the cardio-motor & the cardio-inhibitory centres.

INFLUENCE of the NERVOUS SYSTEM over the ACTION of the HEART.—2nd Tablet.

AGENCIES WHICH GOVERN the CARDIAC GANGLIA.

Vagal or Extra-cardiac Inhibitory Centre, and Cardio-inhibitory Nerve – The influence of the vagal or extra-cardiac inhibitory centre is conveyed to the heart through the *pneumogastric nerve*, and its *superior cardiac branch, or cardio-inhibitory nerve:* – If either of these nerves be divided, the heart beats with *greater frequency & strength.* If either nerve be irritated—or if, after division, the *peripheral segment* of either nerve be irritated—the action of the heart will be, within about $\frac{1}{6}$ of a second, and according to the strength of the stimulus, either *slackened & weakened* (though ampliated), or for a time *entirely arrested in diastole.* The reason why the inhibitory effect is not immediate is that the nerve does not act directly upon the muscular fibres of the heart, but merely stimulates the intra-cardiac inhibitory centre, which centre reacts in its turn upon the muscular fibres. – The vagal centre is *in constant automatic action*, always restraining or moderating the action of the heart; but it may be stimulated to *increased inhibitory action* by increased arterial pressure, by the venous condition of the blood, by irritation of almost any sensory nerve, especially the fifth, or of the abdominal viscera or abdominal plexuses of the sympathetic, by a sharp blow on the abdomen, etc.

Cardio-Motor Centre, and Cardio-Accelerator Nerves – The cardio-motor centre is stimulated by the arterial character of the blood, by mental emotions, and also by the *slight* irritation of almost any sensory nerve. *Accelerator nerves*—or perhaps nerves whose influence modifies merely the distribution of the efforts of the heart in time, in the direction of greater frequency coupled with diminished energy—*descend from this centre partly along the cervical cord of the sympathetic, but mainly through the spinal cord, the rami communicantes to the last cervical & first dorsal ganglia, and the cardiac branches given off by the latter:* – Irritation of the cervical portion of the sympathetic, or of the medulla or upper part of the cervical cord, accelerates the action of the heart.

The acceleration induced by irritation of the medulla or upper part of the spinal cord is, however, a complex phenomenon due in part to irritation of the *vaso-motor centre*, irritation of which centre induces contraction of all the arteries and increased arterial pressure: – Irritation of the medulla or upper part of the spinal cord will accelerate the beats of the heart *even though all the cardiac nerves be divided*, PROVIDED THE SPLANCHNIC NERVES BE LEFT UNINJURED; if, however, the *splanchnic nerves* be divided, or if the spinal cord be divided at the upper part of the dorsal region, so as to do away, by paralysing the greater part of the vaso-motor system, with the influence upon the heart of modified arterial pressure, then irritation of the medulla or of the upper part of the spinal cord will no longer accelerate the beats of the heart unless the cardio-motor nerves remain uninjured throughout the whole of their course.

Depressor Nerve, or Vaso-inhibitory Branch of the Vagus – The *depressor nerve, or vaso-inhibitory branch of the vagus* (Ludwig & Thiry) is an *afferent or sensory nerve* extending *from the heart to the trunk of the pneumogastric* a little below the origin of the superior laryngeal nerve, and which is *in reflex relation through the medulla both with the vagal or extra-cardiac inhibitory centre, and with the vaso-inhibitory centre. If it be irritated*, or if, after division, its *central segment* be irritated, *the action of the heart is first slackened, and then sometimes slightly accelerated:* – *first slackened* through irritation of the vagal centre, from which centre an inhibitory influence is conveyed to the heart through the pneumogastric & cardio-inhibitory nerves; *then slightly accelerated* through irritation of the vaso-inhibitory centre, irritation of which latter centre induces dilatation of all the arteries of the body, diminution of the blood pressure, diminished supply of blood to the medulla, and consequently diminished activity of the previously excited vagal, or extra-cardiac inhibitory centre, and also, probably, diminished activity of the intra-cardiac inhibitory centre.

Poisons which act on the Cardio-motor & Cardio-inhibitory Centres – *Nicotin & Woorara* first stimulate, and then paralyse, the vagal or extra-cardiac inhibitory centre & the cardio-inhibitory nerve; they therefore first slacken, and then accelerate the beats of the heart, and prevent the beats of the heart from being arrested by irritation of the vagus. *Atropin* adds to the latter action that of paralysing the intra-cardiac inhibitory centre, and thus, not only accelerates the heart's action, but prevents its being arrested either by irritation of the vagus or by direct irritation of the intra-cardiac inhibitory centre. *Muscarin* appears to stimulate the intra-cardiac inhibitory centre, for it arrests the heart in diastole, even though the nervous system be previously brought under the influence either of nicotin or of woorara.

FUNCTIONS of the CEREBELLUM.

The cerebellum is either *the organ for the co-ordination of voluntary movements* (Flourens) *or the seat of the muscular sense* (Foville). Either theory explains the experimental facts, but the latter harmonises most with the extreme sensibility of the cerebellar peduncles: the knowledge of the position of the limbs and of the degree of contraction or relaxation of the muscles is as necessary for harmonious action as a regulating or controlling power: – When the cerebellum is removed in successive layers, the two hemispheres being sliced off simultaneously, want of co-ordination in the action of the muscles, and hence weakness and uncertainty and want of harmony in all voluntary movements is the result; and this result becomes more and more marked till the power of walking, springing, flying, or even of preserving the equilibrium, is entirely lost. Partial recovery may, however, take place when a portion of the cerebellum, sometimes not more than one-third, is left; and patients otherwise confined to their bed or to a sick room, may show little or no disturbance of the co-ordinative power, though their cerebellum be extensively diseased.

No other results follow the experiment; the intelligence, the senses, and the motor power (the fact of inco-ordination excepted) remain unimpaired.

The influence of each hemisphere is directed *towards the opposite side of the body:* – When one hemisphere is removed, when one crus is divided, or when the pons is divided on one side of the middle line, the power of co-ordinate movement preserved on the side of the injury, is lost on the opposite side; the animal then falls on the disordered side, and usually turns himself over and over again often as many as sixty times in a minute, the rotation being *from* the side on which the injury was inflicted. Similar movements have been observed in man. – When the crus is divided from behind the rotation is *towards* the injured side (Schiff).

These rotatory movements do *not* appear to be due to the *mere unbalanced action of the muscles of one side of the body*, as was first believed, and they have been attributed of late to the irritation of a peculiar set of spinal fibres not usually employed by the will (Brown-Séquard). They are characterised by a peculiar twisting of the vertebral column in a corkscrew-like manner, the front of the spine rotating first, and then dragging, as it were, the posterior part after it (Longet).

The cerebellum also *influences the movements of the eyeballs.* By irritating different parts of its surface Dr. Ferrier produced every kind of movement of the eyes, even rotation on their antero-posterior axis; these movements were always symmetrical, even when only one hemisphere was irritated.

The cerebellum itself is *insensible,* at least in its superficial parts, but *irritation of its crura gives rise to violent pain.* – Irritation of its deeper parts gives rise to pain and to convulsions (Dalton).

Only conjectures can be added: – It is the organ of physical love (Gall). – It is the great trophic centre (Laycock). – It is neither a sensory centre nor a seat of consciousness, nor is it a part through which the conductors of motion or of sensation pass; no idea, emotion, or voluntary act is suppressed by its being injured (Brown-Séquard).

FUNCTIONS of the MESOCEPHALON.

Sensory impressions appear to be conducted mainly through its central portions, motor impulses mainly through its anterior portions. – The vaso-motor impulses decussating in the anterior pyramids, division of one lateral half of the mesocephalon induces hyperæsthesia in the *opposite side of the body.* – The restiform bodies are not conductors of sensory impressions (Brown-Séquard).

The surface of the mesocephalon does not appear to be directly excitable, but, if the electrodes be passed into the substance of the part, the electric stimulus gives rise both to convulsions & to manifestations of pain (Longet).

Both Longet & Vulpian consider the mesocephalon to be an independent seat of sensation & motor power. "They insist upon the fact that after removal of the whole brain, with "the exception of the tuber annulare and medulla oblongata, irritation of the external "parts or of a sensitive nerve will produce, in dogs and rabbits, cries which are evidently "the expression of a conscious sensation; and according to Vulpian, after extirpation of "the hemispheres and the cerebral ganglia in the rat, movements of the head and limbs "were not only produced by pinching the integument, but blowing suddenly upon one of "the ears caused shaking of the head, accompanied by winking of the eyes; showing that "the animal was still sensitive to ordinary tactile impressions, as well as to those of a "painful character. The same experimenter found that in a rat, after the above "operation, a hissing sound made by the lips excited repeatedly distinct signs of agitation. "From these facts it can hardly be doubted that sensations are actually perceived by the "animal so long as the tuber annulare remains uninjured" (Dalton).

N. – The above facts do not appear to warrant the conclusion which is drawn from them. The reflex power either of the medulla oblongata or of the mesocephalon itself is quite sufficient to explain all the phenomena observed.

FUNCTIONS OF THE CRANIAL NERVES.

P.

MOTOR NERVES of the EYEBALL

Are the *third, fourth, & sixth.*

Third Nerve, or Motor Oculi – Motor with traces of sensibility probably derived from the 5th. Supplies by its superior branch the *levator palpebræ superioris & the superior rectus,* and by its inferior branch the *internal & inferior recti & the inferior oblique* (all the muscles of the orbit except the superior oblique & the external rectus); the latter branch giving off the *short or motor root of the lenticular ganglion,* which root supplies the circular fibres of the iris & the ciliary muscle.

When it is irritated the corresponding muscles become convulsed, and the pupil contracts.

When it is divided or paralysed, –

1. – *The eye looks outwards* through the unbalanced action of the external rectus, and is rotated inwards by the superior oblique.

2. – *The upper eyelid can no longer be raised (ptosis)* through the unbalanced action of the orbicularis palpebrarum.

3. – *The pupil is dilated,* and vision is accommodated for distant objects.

Fourth Nerve, Trochlearis, or Patheticus – Motor with traces of sensibility. Supplies the *superior oblique.* – When the head is inclined to one side *the superior oblique of that side contracts with the inferior oblique of the other.* These muscles thus compensate for the deviation of the head by rotating the eyeballs round their antero-posterior axis in such a way that the corresponding diameters of the two retinæ remain both parallel to each other, and, in all normal positions of the body, in the same relation to external objects. When one of these muscles is paralysed, double vision results, the image perceived by the affected eye being oblique with regard to the other. These disturbances disappear when the head is inclined towards the opposite side.

Sixth Nerve, or Abducens – Supplies the *external rectus.* Its division or paralysis gives rise to internal squint.

The nerve-supply of the muscles of the orbit is *derived from three different sources, apparently in order that the insymmetrical muscles which act together,* – as the right external & left internal recti when both eyes look to the right, and the left superior & right inferior oblique when the head is inclined to the left, – *be supplied by totally different nerves,* and that, in such cases, the tendency be counteracted, which symmetrical muscles have to contract together.

The *sympathetic nerve* supplies the *radiating fibres of the iris.* When it is irritated the pupil dilates, when it is divided the pupil contracts.

FIFTH NERVE.

LESSER or NON-GANGLIONIC PORTION — Conveys motor power to the muscles of mastication :- *temporal*, *masseter*, *both pterygoids*, *mylo-hyoid*, & *anterior belly of digastric.*

GREATER or GANGLIONIC PORTION –

I. – Conveys common sensibility to the anterior & lateral parts of the head, and common & gustatory sensibility to the anterior two-thirds of the tongue. – Its intra-cranial section abolishes the very acute sensibility of these parts (Magendie). It is impossible, however, to destroy completely the sensibility of any portion of the face by section of only one of the three divisions of the 5th nerve, for these divisions anastomose extensively with each other ; – the facial nerve, also, mainly through its anastomoses with them, conveys everywhere some amount of sensibility. – The parotid region & the pinna are also supplied by the great auricular branch of the cervical plexus.

II. – Conveys muscular sensibility to the muscles of the face & lower jaw.

III. – Is the afferent nerve concerned in various reflex actions. – After its division, winking ceases ; irritation of the conjunctiva produces no flow of tears ; irritation of the mucous membrane of the nose, no sneezing. — Through suppression of the ordinary "guiding sensations" the movements of the face become slow & awkward.

IV. – Its section has an injurious influence over the nutrition & functions of the Organs of the Special Sense, – This influence being especially marked when the nerve is divided *in front of the Gasserian ganglion*, and being mainly due, therefore, to the suppressed action of the fibres arising from the ganglion-cells. (Division of the sympathetic retards rather than otherwise the nutritive & functional disturbances; and certainly does not induce them, as was once believed. – Bernard). — *After division of the 5th nerve* :–

Taste, and the common sensibility of the tongue – Are abolished in the anterior two-thirds of the organ (Vide Lingual & Glosso-Pharyngeal nerves).

Smell – Is impaired through congestion, œdema, & hypersecretion of the Schneiderian membrane, and the blocking up of the nares by accumulated mucus ; sometimes through diminished secretion & dryness of the parts.

Hearing – Is impaired, probably through similar causes.

Sight. – Immediately after the operation, the conjunctiva loses its sensibility, and the pupil becomes contracted & immovable (It dilates in cats & dogs). The conjunctiva then inflames & suppurates ; the cornea becomes opaque, and the iris swollen & covered with inflammatory exudation ; finally the cornea sloughs, and the eye is emptied. Occasionally the process subsides, and sight is restored. – The eye remains healthy, however, says Snellen, if it is covered over with the ear, which partly retains its sensibility. The drying up of the surface of the eyeballs (the lachrymal secretion being no longer spread over it by the reflex action of winking), and its unavoidable injury by foreign bodies whose contact is no longer felt, appear therefore to have something to do in initiating the process.

FACIAL NERVE.

The facial nerve is *exclusively motor at its origin.* Further on, however, it becomes *both sensory & motor.* This is due to its anastomoses with the 5th & glosso-pharyngeal nerves, through the petrosal; with the 5th nerve through the auriculo-temporal, the chorda tympani & the terminal branches of both nerves upon the face; with the pneumogastric nerve through the auricular branch of the latter; with the great auricular branch of the cervical plexus; and perhaps also to its anastomosis with the auditory nerve through the portio intermedia of Wrisberg.

The Facial Nerve supplies:

1. — *All the muscles of expression of the face*, including the *platysma* (not the muscles of mastication).

2. — Through the great petrosal nerve & Meckel's ganglion, the *levator palati & the azygos uvulæ.*

3. — Through the small petrosal nerve & the Otic ganglion, *the tensor palati & tensor tympani, and the parotid gland* (secretory fibres running in the course of the auriculo-temporal).

4. — Through its tympanic branch, *the stapedius & laxator tympani.*

5. — Through the chorda tympani, *the submaxillary gland* (secretory fibres traversing the submaxillary ganglion), and the *superior lingualis.*

6. — Through its posterior auricular & muscular branches, *the muscles of the external ear, and the stylo-hyoid & posterior belly of the digastric.*

Its Functional Activity is necessary for the perfect exercise of *sight, hearing, smell, & taste*, and for the maintenance of the *normal expression of the face.* — *When it is paralysed,* —

1. — The *eyelids remain open* — through the unbalanced action of the levator palpebræ superioris. The *tears run down the face* through paralysis of the tensor tarsi muscle & displacement of the puncta lachrymalia; conjunctivitis and corneitis set in, and the sight becomes impaired, though much less extensively than after division of the fifth nerve.

2. — *Hearing is impaired* — through paralysis of the muscles of the tympanum. Sometimes abnormal sensibility to sounds is observed.

3. — *Smell is impaired* — through paralysis of the dilators & compressors of the nostrils, and consequent inability to direct a brisk current of air towards the upper or olfactory part of the nasal fossæ.

4. — *Taste is impaired* — probably through paralysis of the lingualis muscle. — Some physiologists attribute the gustatory properties of the chorda tympani to sensory fibres running in the course of the motor ones; others attribute it to an influence over the circulation & secretion of the tongue similar to that which the nerve exerts in the submaxillary gland.

5. — *The paralysed side of the face is motionless and inexpressive.* The *nostril* is flattened & collapsed. The *eye* has a staring, vacant appearance, mainly due to the hanging down of the lower lid below the level of the cornea. The *angle of the mouth* is depressed, and the *lips* cannot be brought together; hence the labial consonants are but imperfectly pronounced, the saliva tends to escape, a difficulty is experienced in drinking, and, in eating, the food lodges between the gums and the cheek. The mouth, as a whole, is drawn towards the opposite side when the muscles contract. — The soft palate is paralysed when the injury is deeply seated.

When the injury is situated above the nucleus of origin of the facial nerve, both the facial paralysis, and the hemiplegia which usually accompanies it, affect the side opposite the injury. (The fibres of the facial nerve decussate at their origin on the floor of the 4th ventricle, the motor tract to the body generally decussates in the anterior pyramids). When the injury is situated in the mesocephalon, *i. e.* just below the nucleus, and when it therefore affects the facial nerve beyond its decussation, the facial paralysis is on the side of the injury, and the hemiplegia on the opposite side. The decussation of the facial nerve is, however, incomplete, for in facial paralysis on the side opposite the injury the eyelids remain unaffected (Vulpian).

PNEUMOGASTRIC NERVE.—1st Tablet.

The pneumogastric is *both sensory & motor* from its origin.

SENSORY. – Irritation of its roots gives rise to evident manifestations of pain. *Its sensibility is but slight,* however, and, under normal conditions, we are usually unconscious of the impressions it conveys; these impressions give rise, nevertheless, to *important reflex actions.*

MOTOR. – It contains motor fibres of its own, *in addition to those which it derives from the spinal accessory*, and probably also from the facial, hypoglossal & two first cervical. These motor fibres proper to the pneumogastric supply the larynx, pharynx, & œsophagus (as do also the motor fibres which the pneumogastric derives from the spinal accessory); and they may be called into play either directly, – through irritation of the roots of the nerve (Chauveau, Bernard, Vulpian), or reflexly through irritation of the *afferent* fibres of the the spinal accessory (Van Kempen & Thiernesse). – Longet believed the pneumogastric nerve to be entirely sensory.

It bears great analogy to the sympathetic, partly through its frequent anastomoses with that nerve, partly through the fibres it derives from its own ganglia.

Its branches must be examined separately, as the endowments of the parent trunk are very differently distributed among them.

PNEUMOGASTRIC NERVE.—2nd Tablet.

These branches are :—

Auricular – Common sensory nerve to integument of back of pinna; joins both with trunk & with auricular branch of facial.

Pharyngeal – *Principal motor nerve of pharynx & soft palate.* Conveys the reflex motor impulses for the second & third acts of deglutition. – The motor fibres of this nerve are derived to a great extent from the spinal accessory.

Superior Laryngeal – *Mainly sensory:* but contains a few motor fibres for the arytænoid & crico-thyroid, which fibres are partly derived from the spinal accessory. – To this nerve is due the *particularly acute sensibility of the interior of the larynx,* through which sensibility foreign bodies are prevented from entering the air-passages, or, if they enter, are rapidly expelled therefrom by a violent fit of coughing. – Its stimulation inhibits inspiration (Waller & Prévost), and so does also the contact of the food with the base of the tongue at the end of the first act of deglutition. When it is divided a part of the food penetrates into the air-passages.

Inferior or Recurrent Laryngeal – Is *chiefly,* a *motor* nerve, its motor fibres being partly derived from the spinal accessory. It *supplies all the muscles of the larynx except the crico-thyroid, and controls the glottis* both as regards its dilatation or closure, and the relaxation or tension of the vocal cords. When it is divided, or when the trunk of the pneumogastric is divided in the neck, the glottis becomes passively narrowed in inspiration and passively dilated in expiration, instead of being, as it normally is, actively dilated in inspiration & passively narrowed in expiration. Adult animals merely lose their voice after operation, or are, usually at least, but slightly inconvenienced; young animals, whose laryngeal cartilages are more flexible, are immediately suffocated through complete closure of the glottis.

Cardiac – The *Cardio-inhibitory nerve* connects the extra- & intra-cardiac inhibitory centres, and conveys a stimulating influence,—inhibitory as regards the heart,—from the former to the latter. Through this nerve, therefore, the vagal inhibitory centre contained in the medulla, strengthens the controlling influence of the inhibitory ganglia of Ludwig over the cardio-motor ganglia of Remak & Bidder : – If this nerve be divided, or if the trunk of the pneumogastric be divided in the neck, the heart beats with greater frequency & strength ; if either nerve be irritated, or if, after division, the peripheral segment of either nerve be irritated, the action of the heart will be, within about one-sixth of a second, and according to the strength of the stimulus, either slackened & weakened (though ampliated), or for a time entirely arrested in diastole.

The *Depressor or Vaso-inhibitory nerve* conveys sensory impressions from the heart both to the vagal or extra-cardiac inhibitory centre, and also to the vaso-inhibitory centre. If it be irritated, the action of the heart is first slackened, and then sometimes slightly accelerated : – *first slackened* through irritation of the vagal centre, from whence an inhibitory influence is conveyed to the heart through the pneumogastric and cardio-inhibitory nerves; – *then slightly accelerated* through irritation of the vaso-inhibitory centre, irritation of which centre induces dilatation of all the arteries of the body, diminution of the blood-pressure, diminished supply of blood to the medulla, and consequently diminished activity of the previously excited vagal centre, and also, doubtless, of the intra-cardiac inhibitory centre. (Vide Influence of the Nervous System over the Action of the Heart, 2nd Tablet.)

Pulmonary – The pulmonary plexuses are, with the trunk of the pneumogastric, *the principal conductors of the impression of the necessity of breathing.* When both pneumogastric nerves are divided respiration becomes much less frequent, without, however, any sense of suffocation being induced; inspiration is deep & prolonged, expiration is sudden & convulsed (Dalton). After death the lungs are found gorged with blood, dark, heavy, & non-crepitant; and the bronchi are filled with frothy fluid mixed with blood, mucus, and particles of food. The operation does not appear, however, to modify greatly the total quantity of air breathed. – Forcible inspirations may be induced by irritation of the central extremity of the divided nerve; the diaphragm may even be tetanised if the stimulation is sufficiently powerful.

Œsophageal – Division of the pneumogastric nerves destroys both the sensibility & the motor power of the œsophagus; the food then accumulates in the lower part of the canal, and finds its way into the stomach but slowly and only through the effects of pressure from above.

Gastric – The same operation arrests the peristaltic movements of the stomach; and greatly retards the secretion of gastric juice, though it does not entirely arrest it : – Small quantities of food may still be digested (Longet); larger masses are only superficially affected (Bernard). The digestive function is partly or wholly restored, if the animal survives the operation (Schiff).

LINGUAL & GLOSSO-PHARYNGEAL NERVES.

Both nerves convey *both common & gustatory sensibility* to the tongue, – the former nerve to the *anterior two-thirds* of the organ (part in front of the circumvallate papillæ), the latter to the *posterior third* (circumvallate papillæ & part behind them), and also to the sides.

The *gustatory function* of these nerves is *probably restricted to a portion of their fibres*, and due mainly to the influence of the papillæ in which these fibres terminate: – In paralysis of the 5th nerve either the common sensibility alone or the gustatory sensibility alone may be lost in the anterior portion of the tongue, the other kind of sensibility being retained. – It may be added that these nerves do not present the character of nerves of special sense : contrary to what happens in the case of the other nerves of special sense, their irritation calls forth indications of pain.

The *gustatory nerve* supplies a *high degree of common sensibility to the more movable portion of the tongue*, the special functions of which portion are to bring the food again & again within the grip of the teeth, to decide when it is sufficiently masticated, and finally to form it into a *bolus ;* – common sensibility is more acute at the tip of the tongue than in any other part of the body.

The *glosso-pharyngeal nerve* supplies but a *small degree of common sensibility to the posterior & less movable portion of the tongue* (and also to the mucous membrane of the fauces). – The common sensibility of the base of the tongue & fauces is *reflexly connected with deglutition, vomiting, & respiration :* – Deglutition ensues in response to the momentary application of the usual stimulus, *i.e.*, the alimentary bolus; vomiting ensues in response to the prolonged application of any unusual stimulus; inspiration is inhibited during deglutition (probably through a sensory impression conveyed through the superior laryngeal branch of the vagus, which branch sends a few filaments to the mucous membrane of the base of the tongue) ; an inspiratory movement precedes, and a contraction of the expiratory muscles induces, the act of vomiting.

The *gustatory sensibility* which the glosso-pharyngeal nerve supplies to the *same parts* is called into activity *at the close of the first act of deglutition*, when the bolus, pressed between the soft palate & the base of the tongue, glides backwards to the pharynx, and escapes from under the control of the will; – this part of the tongue is the seat of the *after-taste.*

The *gustatory nerve* is *purely sensory.* The *glosso-pharyngeal nerve* is *purely sensory at its origin.* Irritation of its roots does not give rise to any muscular contractions (Longet), except reflexly (Reid). Its communications with the facial & pneumogastric nerves (the communication with the latter nerve being derived, partly or wholly, from the spinal accessory) soon transform it, however, into a *mixed nerve,* whose motor fibres supply some of those muscles, which the afferent fibres of the same nerve call reflexly into play, *i.e.*, the *stylo-glossus & -pharyngeus, digastric,* and *superior & middle constrictors* (Reid).

SPINAL ACCESSORY NERVE.

Is a *motor* nerve closely associated with the pneumogastric, both anatomically & functionally.

It gives motor fibres to that nerve, and receives sensory fibres from it. Its trunk is therefore both sensory & motor, *so long as it is connected with an undivided pneumogastric*, motor only if the roots of the pneumogastric be severed (Bernard). Hence the explanation of the experiments of Van Kempen & Thiernesse: – If the roots either of the spinal accessory or of the pneumogastric be irritated, reflex movements ensue in the pharynx, larynx & œsophagus, and, in addition, if the roots of the spinal accessory be irritated, in the sterno-mastoid & trapezius. If, now, the roots of the pneumogastric be divided, and irritation be again applied to the spinal accessory, no movements will be observed this time, except in the sterno-mastoid & the trapezius.

The experiments & views of Bernard on the special functions of this nerve are full of interest, though they cannot perhaps be received in their entirety. They may be summarised as follows:-

"The spinal accessory nerve presides over the vocal functions both of the larynx & "thorax: by its inner or accessory portion, over those of the larynx; by its outer or spinal "portion, over those of the thorax."

"Its inner or accessory portion supplies those muscles of the larynx, which close the "glottis and tense the vocal cords, and which are therefore called into play when sound is "emitted: – After division of this portion of the nerve the voice is lost, but, contrary to what "happens after division of the pneumogastric or recurrent laryngeal, respiration is unaffected."

"Its external or spinal portion induces in the sterno-mastoid & trapezius an action "antagonistic to that of the expiratory muscles: – For vocal purposes expiration must be "sustained during the whole length of the sound, or succession of connected sounds, which "it is desired to emit; a great point with the orator & and the singer is the careful manage-"ment of his "wind," which must be saved, and be made to last till a pause is reached. "This is done through the sterno-mastoid & trapezius, as called into play by the spinal "accessory. After division of the external branch of this nerve the voice is confined to the "duration of an ordinary expiration and the vocal sound dies off in a kind of sentimental "whine as the end of the expiratory movement approaches; it cannot be prolonged into a "normal cry."

"Closely connected with phonation is the phenomenon of *effort*, also dependent upon "the integrity of the spinal accessory: The internal division of this nerve closes the glottis; "its external division assists in steadying the thorax. Respiration is not visibly affected by "division (or evulsion) of the nerve *so long as the animal is at rest*, but during any exertion, "such as running, or leaping, a want of harmony immediately appears between the respi-"ratory movements & those of the limbs, and results in shortness of breath."

"The special influence of the spinal accessory nerve over the sterno-mastoid & trapezius "does not prevent the ordinary action of these muscles under the influence of the cervical "nerves, which supply them with common motor fibres."

HYPOGLOSSAL NERVE.

Is chiefly, if not entirely, motor from its origin; irritation of its roots gives rise to no manifestations of pain (Longet). *Outside the cranium it becomes both sensory & motor,* its sensibility being probably due to its anastomoses with the pneumogastric, sympathetic, loop between the two first cervical & gustatory. Its degree of sensibility varies, however, in different animals. In the ox, cat, & rabbit it has a distinct sensory root presenting a ganglion.

It supplies the muscles of the tongue, the depressor muscles of the larynx (through its descending branch, which is said by some to be derived from the 1st & 2nd cervical), *and the thyro- & genio-hyoid.* When it is irritated the tongue is convulsed; when it is divided on both sides the tongue hangs down as a helpless mass, and is liable to be caught between the teeth; the sensibility of the organ is not affected by the operation.

The motor power which this nerve communicates to the tongue is essential to *articulation, mastication, & the first act of deglutition*: – The tongue takes part in the pronunciation of nearly all the vowels, and of all the consonants, except the labials (*b, m, p*), & labio-dentals (*f, v*). It brings the successive portions of food between the teeth. After mastication it carries them backward into the pharynx.

Agreeably with the statements of Henle, who describes the hypoglossal nerve, as arising in part from the *corpus dentatum* of the olivary body, it would appear, on pathological grounds, that this nerve has *two distinct connections with the nerve-centres*: – In cases of paralysis, the power of articulate speech may be impaired or lost without the masticatory movements of the tongue being affected; though more rarely, the converse may also be observed (Carpenter). – In paralysis of this nerve the tongue is usually protruded towards the palsied side.

FUNCTIONS OF THE SYMPATHETIC NERVE.

SYMPATHETIC NERVE.—1st Tablet.

May be considered with respect to the *conduction of sensory impressions* & of *involuntary or reflex motor impulses,* and with respect to the *reflex actions of the second, third, and fourth classes.*

Conduction of Sensory Impressions – Is but *imperfectly effected through the sympathetic system,* through which, in the healthy condition, *none but intense & prolonged impressions are perceived:* the viscera are not felt, except when diseased. For manifestations of pain to be elicited through the sympathetic, either caustics or the actual cautery should be applied to the splanchnic nerves or to the semilunar ganglia. – This imperfect conduction of sensory impression is doubtless due to the *obstacle to transmission presented by the ganglia,* in which the sensory impressions may be supposed to be diffused among the nerve cells, and thus to become exhausted before they reach the spinal cord.

Conduction of Involuntary or Reflex Motor Impulses – Is equally imperfect *as regards rapidity.* But the esential characteristics of the movements excited through the sympathetic are that they are *orderly & in every way like the natural movements,* that they are *induced but slowly,* and that the *parts continue to act for a certain time after the stimulus has been removed,* even though they be separated from the cerebro-spinal axis or wholly removed from the body: irritation of the nerves of the stomach & intestine gives rise to the normal vermicular or peristaltic movements of these parts; all are acquainted with the apparently independent action of the heart. – This is doubtless due to the action of the *visceral or parenchymatous ganglia.*

SYMPATHETIC NERVE.—2nd Tablet.

Reflex Actions of the Second, Third, & Fourth Classes - (Vide Classification of Reflex Actions, page 84).

In these classes, sympathetic nerve-fibres form the afferent or sensory nerve, or the efferent or motor nerve, or both, respectively as follows: -

Reflex Actions of the 2nd Class - The *afferent or sensory nerve* in the case of the mechanical thoraco-abdominal functions, i.e., *Muscular contractions in breathing, coughing, vomiting, etc.*

Reflex Actions of the 3rd Class - The *efferent or motor nerve* in the case of the vaso-motor reflex actions, which govern the nutrition & the secretions of the body generally.

Reflex Actions of the 4th Class - *Both afferent & efferent nerves* in the case of the reflex movements of the thoraco-abdominal viscera, and in the case of the vaso-motor reflex actions which govern the nutrition & the secretions of these viscera.

Division of the cervical cord of the sympathetic, or excision of the superior cervical ganglion, induces *dilatation of the vessels of the corresponding side of the head and neck*, and, through freer flow of blood through the capillaries, *stimulation of the vital properties of all the tissues*. Thus, after the operation, the cheek becomes flushed, hot, covered with perspiration, and the growth of the hair is accelerated. The cutaneous sensibility, and that of the organs of the senses, is increased: the pupil contracts, the eyelids close, the tears flow; the muscles respond more readily to any irritation. Rapid cell growth leads to general hypertrophy, and to increased tolerance of injury, or, if a wound have been inflicted, to more rapid healing. *Stimulation of the sympathetic*, or of its upper cut extremity, *reverses the phenomena*. - Similar effects may be induced in any part of the body.

SYMPATHETIC NERVE.—3rd Tablet.

To the doctrine of vaso-motor reflex action, as it is generally received, have recently been added both the rival theories of *active arterial dilatation* (Schiff), & of *arterial peristaltic action* (Legros & Onimus), and that of the nutritive & secretory influence of certain *trophic* (Samuel) & *excito-secretory nerves* (Ludwig), which nerves are said to arise in the ganglia on the posterior roots of the spinal nerves and to run centrifugally with the fibres of these nerves.—

Thus the "*passive or neuro-paralytic hyperæmia*" above described may be surpassed in degree, it is said, by the "*active hyperæmia*" resulting from the direct irritation of certain efferent nerves; and the erection of the penis through irritation of the *nervi erigentes*, the increased vascularity of the submaxillary gland through irritation of the chorda tympani, and the phenomenon of blushing, are given as cases in point.

The admission of the *active dilatation of arteries* involves, however, the view, either that the arteries contain longitudinal muscular fibres, which is contrary to evidence, or else that muscular fibres can elongate forcibly.

Vermicular or peristaltic action of the arteries has been observed, it is said, in the annelida & the web of the frog's foot, and even occasionally in the human eye; and such peristaltic action may always be induced, it is added, by *slight* stimulation of those same nerves, whose more intense irritation produces tetanic contraction.

The admission of three conditions or modes of action of arteries—the intermediate condition, in which the elasticity of the arterial walls comes mainly into play; the state of moderate stimulation, leading to peristaltic action & hyperæmia; and the state of more intense stimulation, leading to tetanic contraction & anæmia—would better explain the succeeding extremes of vascularity, – as when the pallor of rage or terror follows upon the flush of a more moderate emotion, – than the two conditions hitherto believed in.

Samuel's *trophic nerves* are *not shown to be distinct from the vaso-motors* by the fact that irritation of the superior laryngeal, vagus, or sciatic, induces laryngitis, pneumonia, or inflammatory swelling of the lower limb; neither do other experimental facts supply any further proof of their special character: – Muscles paralysed by the division of their nerves do not lose their normal structure if kept in a state of activity by occasional electric stimulation; and the inflammation & destruction of the cornea & eyeball consequent upon division of the 5th nerve appear to be due to loss of sensibility of the eye & eyelids, leading to dryness of the parts & to the entrance of foreign bodies, rather than to the suppression of any nutritive influence, either of the 5th nerve or of the sympathetic. In the lower animals, and in the lowly organised tissues of the higher animals, nutrition is influenced but very indirectly through the nervous system.

The existence of *excito-secretory nerves* seems to be *better established* by the flow of saliva induced by irritation of the chorda tympani, or of either the auriculo-temporal, gustatory, or glosso-pharyngeal nerve *after the circulation through the gland has been arrested* (Ludwig). It would appear therefore that the supply of blood to a gland is, to a certain extent, subordinate, as regards secretion, to the change produced in the gland-cells themselves through the direct influence of the glandular nerves; though an abundant supply of blood is, of course, necessary to furnish the materials for any copious discharge.

(For Action of the Sympathetic on the Iris, Vide Medulla Oblongata, 2nd Tablet).

THE SENSES.

THE EYE

Is a complete camera presenting :-

Dark Chamber, – Lined by choroid;
Refracting Surfaces, – Cornea, lens;
Media, – Aqueous, vitreous;
Diaphragm, – Iris;
Screen, – Retina, destined to receive inverted images of external objects, which images are seen on removal of a small portion of the sclerotic & choroid from back of eye.

The anterior & posterior surfaces of the cornea being very nearly parallel to each other, and the refractive power of the cornea being moreover very nearly the same as that of the aqueous humour, the slight refraction at the posterior surface of the cornea is neglected in the "diagrammatic eye." The refractive power of the vitreous humour is very nearly the same as that of the aqueous. The refractive power of the lens is somewhat greater in its central than in its peripheral portions.

Emmetropia, Myopia, Hypermetropia, Presbyopia.

In the *normal or emmetropic eye,* the far limit of accommodation is at an infinite distance, and the near limit is at about 10 or 12 cm. No accommodation is required for distant objects, and the range of distinct vision is very great.

In the *myopic or short-sighted eye,* both the far limit & the near limit are brought nearer the eye. The near limit is at 5 or 6 cm., the far limit at a variable but not very great distance.

In the *hypermetropic, or originally long-sighted eye,* both the far limit & the near limit are removed from the eye; or, more correctly, the near limit is removed to a variable distance, and the far limit is so far removed that it no longer exists.

In the *presbyopic eye, or long-sighted eye of old people,* the near limit is removed from the eye, while the far limit is (or may be) unaffected.

Both myopia and hypermetropia are the results of *defective* mechanism; the defect lying either in the antero-posterior diameter of the eye being too long (myopia) or too short (presbyopia), or in the focusing power of the lens being too great (myopia), or too little (presbyopia), or in both conditions combined. The *myopic* eye is too long in its antero-posterior diameter, or its lens is too thick; parallel rays are therefore brought to a focus in front of the retina. The *hypermetropic eye* is too short in its antero-posterior diameter, or its lens is too flat; parallel rays tend therefore to converge behind the retina. The myopic eye can, without any effort, see near objects, and, with an effort, very near objects; it cannot see distant objects. The hypermetropic eye must make some effort to see even distant objects, and a great effort to see near objects; no effort whatever can adapt it to see very near objects.

Presbyopia is the result of diminished power of adaptation or of *impaired* mechanism, due either to increased density of the lens, or to weakening of the ciliary muscle.

Scheiner's Experiment Demonstrating the Accommodation of the Eye.

Take a card, and prick two pin-holes near to each other (the distance between them being less than the diameter of the pupil). Through these pin-holes look at two pins' heads placed one before the other. If the attention be fixed upon the nearer one, the farther one will be seen double & blurred, and *vice versa.*

Further, if, while the farther pin's head is seen double, the right-hand hole be blocked up, the right-hand image of the farther pin's head will disappear. If, while the nearer pin's head is seen double, the right-hand hole be blocked up, the left-hand image of the nearer pin's head will disappear, and *vice versa.*

Experiments of Purkinje & Helmholtz demonstrating the Dioptric Phenomena of Accommodation.

If a light be held before the eye, three reflected images of the flame will be seen by a by-stander, one large bright & superficial, reflected from the anterior surface of the cornea; one smaller, deeper & less bright, reflected from the anterior surface of the lens; one smaller, deeper still & inverted, reflected from the posterior surface of the lens.

If these images be carefully watched while the eye experimented upon is alternately accommodated for distant and for near objects, the image reflected from the anterior surface of the lens will be found to vary in size & position; the other images, on the contrary, will not vary. During accommodation for near objects, the image reflected from the anterior surface of the lens becomes smaller & more superficial, showing that the anterior surface of the lens moves forward, and becomes more convex; during accommodation for distant objects, the image on the anterior surface of the lens sinks deeper into the eye, and becomes larger, showing that the anterior surface of the lens moves backwards and becomes less convex.

Mechanism of Accommodation for Near Objects.

1.– Through the ciliary muscle drawing forward the choroid & ciliary processes, and thus relaxing the suspensory ligament of the lens, the latter bulges forward by virtue of its elasticity, and the convexity of its anterior surface becomes increased.

2. – The pupil contracts, so as to cut off the more divergent rays from the less refracting peripheral portion of the lens.

Accommodation for *distant objects* is merely a passive return to the state of rest.

It was believed for a long time that the mechanism of accommodation consisted in the movement of the lens alternately backwards & forwards, and in the alternate shortening & lengthening of the axis of the eye by the action of the straight & oblique muscles. The circumstance that, in the above experiments, the images on the posterior surface of the lens & anterior surface of the cornea are not affected, contradicts these theories—the first one, directly,—the second one indirectly, for any change in the shape of the eye-ball would necessarily affect the curve of the cornea, and consequently the image reflected from its surface. Besides, pressure upon the eye-ball would act injuriously by rendering the retina anæmic & consequently less sensitive.

Movements of the Pupil.

The pupil contracts when the retina or the optic nerve is stimulated (as when light falls on the retina), when the eye is turned inwards and accommodated for near objects, under the influence of calabar bean, etc. The pupil dilates when the stimulation of the retina or optic nerve is arrested or diminished (as when light ceases to fall on the retina), when the eye is accommodated for distant objects, under the influence of atropin, etc.

The contraction & dilatation are produced by the circular & radiating fibres of the iris, and also to some extent, perhaps, by variations in the vascular condition of the organ.

These movements are governed by reflex action, as follows: – The afferent nerve is the optic nerve. For contraction, the efferent or motor nerve is the third or motor oculi arising from a centre in the corpora quadrigemina. For dilatation, the motor nerve is the cervical sympathetic arising from the cilio-spinal centres in the medulla & the upper part of the spinal cord.

It appears probable that these nerves act on the muscular fibres, not directly, but indirectly through the ganglion-cells in the choroid & the iris. This is shown by the facts that, after the third nerve has been divided and the pupil has dilated under the influence of the sympathetic, *further* dilatation may be induced by the action of atropin; and that, after the sympathetic nerve has been divided, and the pupil has contracted under the influence of the third nerve, *further* contraction may be induced by the action of calabar bean. In these cases, the atropin and the calabar bean must act upon some local mechanism, probably the ganglion-cells above mentioned; and, if that be admitted, it must further be admitted that the nerves themselves act through the same local mechanism.

The two centres for the contraction of the pupils are co-ordinated, and act together: irritation of one retina induces contraction of both pupils.

Some of those fibres of the sympathetic which act upon the pupil join the Gasserian ganglion, and run in the course of the ophthalmic division of the 5th, the nasal, & the long ciliary nerves: division of the 5th nerve causes contraction of the pupil, irritation of the peripheral portion of the divided nerve causes dilatation. Other fibres reach the eye through the cavernous plexus, the lenticular ganglion, and the short ciliary nerves.

The Retina.

The sensitive layer of the retina, *i. e.*, the layer in which the impressions of light originate, is the layer of the rods & cones. This is shown by the calculations of H. Müller based upon Purkinje's experiment of the *vascular tree:* The vessels of the retina (the branches of the arteria centralis retinæ & the corresponding veins) lie at first upon the anterior layers of the retina, through which layers they project their shadow upon the posterior ones. It is only the force of habit that prevents us, under ordinary circumstances, from perceiving this shadow, for if, while the eye is looking into the dark, a ray of light be made to fall very obliquely upon the retina (either by transmission through the coats of the eye, or after reflection on the inner surface of these coats), the shadow will immediately appear; and if now the luminous body be displaced, the shadow will be found to move accordingly.

According to Schultze, the cones are affected by differences of colour, and the rods by differences of brilliancy, or intensity of light.

The region of distinct vision is limited to the *macula lutea*, or perhaps even to the *fovea centralis.* From this point the sensibility of the retina diminishes rapidly, though irregularly in different directions; the area of "indistinct vision" varies considerably in extent in different individuals. – The object of the movements of the eye-ball is to bring the images of the objects observed upon the macula lutea. The optic disc or "blind spot" is almost insensible.

In binocular vision, singleness of perception depends on the two images of the same object falling upon corresponding parts of the two retinæ. The upper halves of the two retinæ correspond to one another, and so do also the lower halves; the inner half of one retina corresponds to the outer half of the other, & *vice versa.* – The two blind spots not being corresponding parts, each eye supplies that part of the field of vision which is wanting in the other.

We judge of the *distance* of an object partly by the effort necessary on the part of the muscles of the orbit to bring the axes of the two eyes to converge upon it, and partly by the effort necessary on the part of the ciliary muscle to bring its image to a focus upon the retina.

By the same means do we judge of *solidity* or *shape*; our discrimination being aided by the slight difference between the images perceived by the two eyes.

Our appreciation of the *size* of an object is based partly on its *apparent* size, *i. e.*, the angle it subtends, and partly upon its supposed distance.

A transitory stimulus may produce a visual impression of greater duration than itself; hence the phenomena of *after-images*, *positive*, & *negative.*

One image may react more or less on another; hence the phenomena of *irradiation* & *contrast.*

Though the most admirable of all optical instruments, since alone it possesses the power of self-adaptation to distances, the eye frequently presents slight imperfections, such as *spherical & chromatic aberration*, *astigmatism*, *etc.*

HEARING.

Sonorous vibrations being transmitted with difficulty from the air to solids & liquids, the auditory apparatus is supplied to *increase* our power of hearing. Sonorous waves can, however, reach the auditory nerve through the bones of the skull.

The Concha.

The large & movable concha of the mammalia generally serves to collect the waves of sound, and to direct them towards the tympanum; the small & fixed human pinna is of relatively little use.

The Membrana Tympani.

Of all solids, those that are most easily set to vibrate under the influence of aerial waves, and which are the best conductors of sound, are those which have one diameter very much greater or very much smaller than the others, or very great as compared to the length of the sound waves, *e. g.*, tensed cords & membranes.

The membrana tympani, through being slightly depressed in the centre, is especially susceptible to sonorous vibrations reaching it through the auditory meatus. It has also the peculiar advantage of having no note of its own, and therefore of being able to answer to vibrations of very different wave-lengths. Its degree of tension, and therefore its power to vibrate, is further increased or diminshed by the action (reflex) of its tensor & laxator muscles. (The latter is considered by some to be merely a ligament.)

The Auditory Ossicles.

These transmit the vibrations of the membrana tympani to the membrane of the fenestra ovalis (annular ligament) with increased intensity but diminished amplitude, for they form together a compound lever of which the long arm—manubrium of the malleus, which receives the vibrations of the tympanic membrane—is twice as long as the short one—long process of the incus, which acts in its turn upon the stapes. – The fulcrum, or axis round which this lever rotates, is an imaginary line passing through the processus gracilis & head of the malleus, and the body & short process of the incus, to the point of attachment of the latter process to the posterior wall of the tympanum.

The ossicles cannot be considered as perfect conductors, for, on the one hand, they are somewhat loosely articulated together, and, on the other, neither of their diameters is very much greater or very much smaller than the others, or very great as compared to the length of the sound-waves.

The other medium of conduction of sonorous waves through the tympanum is the air which that cavity contains, which air is maintained in equilibrium of pressure with the external air by means of the *Eustachian tube.* The Eustachian tube serves further for the exit of mucus; it is opened during the second act of deglutition, but is probably closed at other times

The Labyrinth.

The sonorous waves transmitted to the perilymph by the membrane of the fenestra ovalis traverse the vestibule to reach, on the one hand, the semicircular canals, and on the other, the cochlea. In the vestibule & semicircular canals, they are transmitted to the membranous labyrinth & to the endolymph which it contains, and are supposed to throw the auditory hairs into vibration;* the otoliths are supposed to intensify the vibrations. In the cochlea, the waves run up the scala vestibuli to the cupola, and then descend the scala tympani, and end in impulses against the membrane of the fenestra rotunda. – The stapedius muscle is supposed to regulate the movements of the stapes, and to prevent its being driven too far into the vestibule through any sudden displacement of the membrana tympani. It draws the stapes backwards; in so doing, it presses the back part of the stapes into the fenestra ovalis and withdraws the front part, and, perhaps, gives rise to a wave.

* It must not be forgotten that the semicircular canals have duties apart from conscious hearing. – Vide "Guiding Sensations," or 3rd Tablet on Reflex Action.

Organ of Corti.

It seems probable that the organ of Corti is in some way connected with the appreciation of the number and relative prominence of the several tones & overtones, which enter into the composition of almost every sound; and the long series of the rods, varying regularly as they do both in length and in span of arch from one end of the organ to the other, is suggestive of the hypothesis that each pair responds to vibrations of a specific wave-length, as do the strings of a piano or harp. These rods would thus effect the analysis of complex sounds. In opposition to this theory stands, however, the fact that the variations in length of the rods appear too little to allow them to answer, as do the cords of a musical instrument, to all the sounds that we hear; moreover the rods are absent in birds. On the other hand, the basilar membrane is tense radially but loose longitudinally, *i. e.*, in the direction of the length of the spiral canal. It may therefore be considered to consist of a number of strings radiating from the lamina spiralis ossea to the outer wall of the spiral canal. These strings vary in length much more than the rods of Corti; and it is further possible that they may be more or less tensed by the action of the muscular fibres described by Todd & Bowman in the ligamentum spirale. It is with some show of reason, therefore, that Hensen suggests that this basilar membrane might supply the analysing apparatus first sought for in the rods. According to this view sonorous waves, on reaching the scala tympani of the cochlea, would set into vibration special portions of the basilar membrane, which portions would so act in their turn upon the overlying structures as to give rise to the corresponding impression of sound.

Musical sounds are due to periodical vibrations. *Noises* are due to vibrations which are not periodical, or the periodicity of which is too complex to be easily appreciated.

The *loudness* of a sound depends upon the amplitude of the vibrations which cause it. The *pitch* depends upon the wave-length of the vibrations, or upon the number of vibrations per second.

The *quality* of a sound depends on the number and relative prominence of the overtones which accompany the fundamental tone. These overtones vary greatly from one instrument to another, the same note being struck in both instruments.

The range of ordinary appreciation of musical sounds lies between about 40 and about 4000 vibrations per second. Most persons can recognise the lowest base C (33 vibrations) and the highest treble C (4224 vibrations). The impression produced by vibrations below 30 in number may be felt, if the vibrations are sufficiently powerful, but it cannot be heard. Many persons can hear sounds produced by as many as 16000 vibrations per second, and some can hear sounds produced by as many as 38000 vibrations; but such sounds, when audible, cannot be distinguished with any degree of accuracy.

When instruments not quite in tune are sounded together, the interference of the vibrations produces an alternating rise & fall of the sound known as "beats." When the beats are as many as about 130 per second they become fused, and cease to be recognised; but just before they disappear they give a peculiar roughness to the sound.

SMELL & TASTE.

SMELL

Appears to originate in the contact of odoriferous particles with the spindle-shaped olfactory cells described by Max Schultze (Vide Tablets of Anatomy).

It appears necessary that the vehicle of these odoriferous particles should be a gazeous medium: When the nostril is filled with rose-water, the odour of roses is not perceived.

The sensation takes some time to develop, and when developed, lasts a considerable time. Stimulations, when too often repeated, fail, however, to awake the sensation.

Sensations other than sensations of smell may also be perceived through the nose: Pungent substances, such as ammonia, give rise to sensations essentially different. These two kinds of sensations are conveyed by different nerves, the former by the olfactory nerve, the latter by the fifth: – After division of the olfactory nerve, animals are still affected by ammonia (Magendie); but they have lost the special sense of smell (Biffi). – It should be added that smell may be impaired by division either of the fifth nerve, or of the facial; after the division of the fifth nerve, the impairment is due to imperfect nutrition of the Schneiderian membrane (V. page 100); after division of the facial nerve, it is due to paralysis of the dilators & compressors of the nostrils, and to the consequent inability to direct a brisk current of air towards the upper or olfactory part of the nasal fossæ (V. page 101).

TASTE

Has its seat in the tip, edges, and back part of the tongue, the soft palate with its anterior pillars, and the back part of the hard palate; the middle of the dorsum of the tongue is but slightly endowed with taste. – It must be added that the perfection of the sense of taste is due to many sapid substances also affecting the sense of smell.

To be tasted, sapid substances must be in solution, or at least soluble; and the mouth must be moist. Large surfaces of contact, friction, or pressure of the sentient surfaces one against the other, etc., favour the production of the sensation, as does also a temperature of about 40° C.

The sensation takes a long time to develop, and then endures a long time. When well marked, these prolonged sensations constitute what is called the *after-taste*.

For the special functions of the *Lingual & Glosso-Pharyngeal Nerves*, & the *Chorda Tympani*, see pages 104 & 101.

For the description of the so-called *Taste-buds*, see Tablets of Anatomy. These organs are now believed not to be connected with the sense of taste, since they are found on the epiglottis which is not endowed with taste.

GENERAL DEVELOPMENT OF THE EMBRYO.

OVA.

In the oviparous classes of vertebrates—*birds, reptiles, fishes*—in which the development of the embryo takes place after the ovum has been deposited by the parent, a considerable amount of nutrient material is provided within the yolk, which is of *large size, rich in granular protoplasmic matter, opaque, & highly coloured.*

In the viviparous class—*mammals*—in which the embryo is developed within, and derives its nourishment from the parent, the ovum is *small*, and contains but a *small yolk*, which yolk is also *less rich in granular protoplasmic matter*, and is *pale, clear, & lympid.*

The one ovum is *partly formative & partly nutritive*, and is termed "*meroblastic.*"

The other is entirely, or *almost entirely, formative*, and is termed "*holoblastic.*"

THE TWO KINDS of OVA.

HOLOBLASTIC OVUM.

The holoblastic ovum is *small.*

Its *vitelline membrane* is *thick & transparent,* and forms the *zona pellucida.*

The *germinal or formative yolk entirely fills the vitelline membrane.* It is *pale & limpid,* and contains but a small amount of granular protoplasm. First towards its centre, and then towards the periphery, is the *germinal vesicle* with the *germinal spot,* the latter spot being turned towards the periphery.

Its average size is about $\frac{1}{100}$ of an inch; the human ovum varies from $\frac{1}{120}$ to $\frac{1}{240}$ of an inch. – The germinal vesicle varies from $\frac{1}{750}$ to $\frac{1}{3000}$ of an inch.

MEROBLASTIC OVUM (Hen's Egg).

The meroblastic ovum is *large.*

Its *vitelline membrane* is *thin,* often granular, sometimes indistinctly fibrous, and lined internally with a stratum of nucleated cells, the *epithelial layer.* There is *no pellucid zone.*

The *yolk* is *large, rich in granular protoplasm, opaque, & highly coloured.* At first it appears uniform throughout, but it is soon seen to divide into two parts, the *germinal yolk,* & the *nutritive yolk.*

The *germinal yolk* is *paler & more fluid,* and contains a smaller amount of oil globules. In its midst is the germinal vesicle with the germinal spot. On the surface of the ovum, it forms the *cicatricula* or *germinal disc,* a small whitish spot always situated on that part of the surface which, as is explained below, turns upwards when the egg is laid upon its side. Beneath the cicatricula, the germinal yolk extends downwards towards the centre of the ovum into an expanded cavity, the *latebra.*

As the hen's egg descends along the oviduct, a coating of albumen, the *white,* supplied by the mucous membrane of the canal, is added to its surface. In consequence of the rotatory movement imparted to the egg by the folds of the mucous membrane, this coating is deposited in *spirally arranged layers;* and towards the poles are *two particularly dense and twisted portions,* the *chalazæ,* to which the yolk is so to speak suspended. These chalazæ are attached to the yolk a little below its centre, on the side *opposite* the cicatricula; therefore, as the yolk is lighter than the albumen and tends to float, the cicatricula must always rise to the top when the egg is laid upon its side; in the nest, it is the part first warmed by the hen.

In the lower part of the oviduct, the egg acquires its last covering, which, becoming calcified in its outer portions, forms the *shell* & the *shell membrane,* the former perforated by minute vertical canals for the interchange of gases. The *shell membrane* consists of several strata of finely matted fibres. At the larger end of the egg it splits after a certain time into two layers, between which is formed the *air space,* the air contained in which space is believed to assist in the respiration of the embryo chick.

The *yolk* contains 17 per cent. of albumen, 29 per cent. of fatty matter, a little phosphorized fatty matter, salts, & 52 per cent. of water. The *white* contains 11 per cent. of albumen, salts, extractive matters, a small quantity of fatty matter, & 84 per cent. of water. The *shell* is composed of 96 per cent. of carbonate of lime, 2 of phosphate of lime, & 2 of animal matter.

MENSTRUATION, OVULATION.

The menstrual discharge is a *thin, dark, sero-sanguineous* fluid of a *peculiar & fœtid odour.* It contains either *uncoagulated blood* or broken down clot, uterine & vaginal *mucus* with a watery fluid or *serum, epithelium,* & the *débris of the decidua menstrualis* (J. Williams).

This *decidua menstrualis* is the *mucous membrane of the body of the uterus.* This mucous membrane becomes thick, dark, & congested at every menstrual period, in preparation for the reception of the fecundated ovum, should fecundation take place. Should fecundation not take place, the decidua menstrualis undergoes disintegration; its vessels are laid open, hemorrhage follows, and the membrane itself is thrown off.

The blood which is poured out, either does not coagulate on account of the admixture & dilution above described, or it coagulates but very imperfectly, and the coagulum soon breaks down.

Menstruation therefore is not the simple result of congestion of the uterus arising from the maturation & rupture of a Graafian follicle and the discharge of an ovum. The flux may occur without any Graafian follicle being ruptured; and ova may be discharged without any flux occurring. The presence of an ovary is, however, a necessary condition for menstruation.

It is now clearly made out that the discharge of the ovum usually occurs a little before, or at the commencement, of the menstrual period, exceptionally towards its close or afterwards (J. Williams, Lowenthal). Conception, also, usually occurs before, and not after the menstrual period.

Menstruation usually commences in this country, and in others of similar latitude, *between* the ages of *fourteen & fifteen,* in warm climates the flux appears a little earlier. Its appearance is accelerated by habits of indolence & luxury, and by early sexual excitement. The several periods usually occur at intervals of a lunar month; and the ordinary duration of each period is from *three to six days.*

THE CORPUS LUTEUM

Is a transitory cicatricial development, which occurs during the obliteration of the ruptured Graafian vesicle.

For the first three weeks, the evolution of all corpora lutea is the same:-

Immediately after the escape of the ovum from the Graafian vesicle, a slight hemorrhage takes place into the cavity of the latter. Part of the effused blood doubtless issues into the peritoneum; but the greater part is retained in the vesicle, for the opening made by the ovum during its escape was a very small one (usually not more than $\frac{1}{25}$ of an inch in diameter).

This blood soon coagulates; and the Graafian vesicle, distended by the clot, forms the corpus luteum in its first stage.

Two series of changes now take place: on the one hand, the clot shrinks, hardens, and loses its dark colour; on the other, the wall of the vesicle thickens more & more every day, especially in its deeper part, and becomes convoluted, and variously altered in colour.

By the end of the third week, the corpus luteum has developed into a well defined rounded tumour, $\frac{3}{4}$ of an inch wide, $\frac{1}{2}$ an inch deep, marked on its surface by a small cicatrix corresponding to the ruptured point of the vesicle. On section, the clot is of a gray or light greenish colour, more or less mottled with red, and semi-transparent; and the wall is of a yellowish or rosy hue, $\frac{1}{10}$ of an inch thick in its deepest part.

The corpus luteum of menstruation diminishes after the third week.

It diminishes rapidly during the fourth week, losing nearly one-half. On section, at the end of the fourth week, the clot is considerably shrunk, quite pale, and slightly adherent to the wall; the latter, through undergoing fatty degeneration, has turned of a bright yellow.

The process now advances more slowly. The clot, reduced to a small shrivelled reddish white mass, blends with the wall, which becomes friable, less coloured, and finally confounded with the surrounding tissues. By the eighth or ninth week there is left but a yellowish cicatrix-like spot, one-fifth of an inch wide.

The corpus luteum of pregnancy continues to increase until the fourth month, when it reaches the size of 1 inch by $\frac{3}{4}$. The wall is then $\frac{1}{5}$ of an inch thick, and of a dull or slightly faded yellow; the clot is colourless & purely fibrinous.

Scarcely any change takes place during the 5th & 6th months.

Then comes on the process of atrophy above described. This proceeds but slowly until birth, when the corpus luteum is still $\frac{1}{2}$ an inch wide by $\frac{1}{3}$ of an inch deep, though somewhat softer, more vascular, and less distinct in colour & structure.

After birth resorption proceeds rapidly, and what remains after eight or nine weeks is scarcely distinguishable, except upon a close examination. Some traces may remain, however, for eight or nine months.

PRELIMINARY TRANSFORMATIONS of the OVUM

Are the segmentation of the yolk, the formation of the blastodermic membrane, the delimitation of the area germinativa, & the appearance of the area pellucida.

After fecundation the germinal vesicle disappears, and a new cell, the embryo cell, is formed in its stead (Bischoff, Coste, Robin), which new cell divides and subdivides into two, four, eight, sixteen, ... an indefinite number of nuclei.

The yolk then gathers round the divisions and subdivisions of the central vesicle so as to form two, four, eight, sixteen, ... an indefinite number of nucleated segments of the primitive yolk. – This cleavage or segmentation transforms the yolk first into a mulberry looking mass, and subsequently into a granular collection of minute spheroidal cells.

These cells pass to the periphery of the ovum. Here they arrange themselves in a continuous layer on the inner surface of the vitelline membrane, become flattened by mutual pressure, and constitute the blastodermic or germinal membrane. The central part of the ovum becomes at the same time clear & transparent.

The cells of the blastodermic membrane accumulate at one point, and form a slightly opaque spot, the area germinativa. – This area is at first small & circular, but it soon increases in size and becomes oval & pear-shaped, its longitudinal axis corresponding to the longitudinal axis of the future embryo.

A clear transparent space, the area pellucida, appears in its centre, and similarly extends & assumes a similar form. This space is bounded by an opaque white line due to a peripheral accumulation of cells & nuclei.

The blastodermic membrane splits into two layers, the upper, outer, or serous layer, or *epiblast*, and the under, inner, or mucous layer, or *hypoblast*. A third or middle layer, the vascular layer, or *masoblast*, soon appears between the two others.

Now are formed the first rudiments of the embryo & of its appendages :

In the long axis of the area pellucida, that is to say in the long axis of the future embryo, appear superficially the *primitive trace or groove*, and beneath this, the *chorda dorsalis* or *notochord*. The primitive groove is bounded by, or comprised between, two longitudinal plates, or thickened portions of the blastodermic membrane, termed the *laminæ dorsales*.

GENERAL DEVELOPMENT of the EMBRYO.

The *primitive trace* or *groove* is a shallow furrow which appears on the outer or serous layer of the germinal membrane in the long axis of the area pellucida, and consequently in the mesial line of the future embryo. It is widest at its anterior or cephalic end, in which situation it soon developes into three recesses or vesicles corresponding to the three primary divisions of the future encephalon.

The *chorda dorsalis* or *notochord* is a semi-opaque thread situated beneath the primitive groove. It consists of a linear mass of cells. It forms the basis round which the bodies of the vertebræ are subsequently developed.

The *laminæ dorsales* are seen at an early period to be formed by the *outer layer* and by *part of the middle layer* of the germinal membrane. They thicken into two prominent masses on either side of the primitive groove, and then divide into *dorsal plates & ventral plates*, both of which plates are formed in part by *both outer & middle germinal layers*.

The *dorsal plates* rise up on either side of the primitive groove, which thus becomes deeper & deeper, they then divide into *medullary & posterior vertebral plates*, which plates are formed respectively, the one by the *outer*, the other by the *middle germinal layer*. These medullary & posterior & vertebral plates both unite in the median line, giving rise respectively, the one to the *primitive tube of nervous substance*, the other to the *posterior wall of the neural or posterior perivisceral cavity*.

The *ventral plates* give off the *anterior vertebral plates*, which proceed from the middle germinal layer. These anterior vertebral plates grow inwards round the chorda dorsalis, in front of which they unite.

On either side of the chorda dorsalis, the portion of the middle layer included in the ventral plates swells out into the *intermediate cell mass* or *common reproductive cell mass*, and externally to this cell mass this portion of the middle layer splits into two divisions, the *somatopleure & splanchnopleure*.

(The *intermediate cell mass* or *common reproductive cell mass* is so called because it is comprised between the portion of the middle layer which forms the vertebral plates and the point of division of these vertebral plates into somatapleure & splanchnopleure, and because the genito-urinary glands both of the male & female are subsequently developed from it.)

The *somatapleure divisions* join on either side with the outer layer or epiblast. Both together then bend downwards and inwards towards the corresponding parts of the opposite side with which they unite in the median line, enclosing the anterior perivisceral or hæmal cavity.

The *splanchnopleure divisions* join on either side with the inner layer or hypoblast, and both together develop into the *remainder of the thoraco-abdominal organs*. The splanchnopleure forms the bulk of the thoraco-abdominal organs; the internal germinal layer forms only the epithelial lining of the alimentary canal, of its glandular appendages, of the urinary tract, & of the air passages, even this much being denied by Reichert, Longet & others with respect to the air passages.

The mode of closure of the anterior perivisceral cavity is simple in the thoraco-abdominal region, and similar to the mode of closure of the neural cavity behind: – The external germinal layer gives rise in both cases to the cuticle & its appendages, and the middle germinal layer to the true skin, the bones, muscles, vessels, & peripheral nerves; – it takes place however much later, and is not completed before birth. – In the cervico-facial region the closure of the anterior perivisceral cavity takes place by means of the four branchial arches, which will be described with the development of the face.

The limbs are developed by simple extension of the ventral plates, the middle germinal layer forming the bones & all the soft parts with the exception of the epidermic covering & its appendages, which latter are supplied from the external germinal layer. The limbs first appear as small knobs on each side of the trunk. As they extend, they show traces of division into their respective segments, and their extremities expand & flatten, and exhibit indentations which demarcate the future fingers & toes.

The space between the somatopleure & the splanchnopleure becomes the pleuro-peritoneal cavity.

INFLECTION of the BODY-WALL. HEAD, TAIL, & SIDE FOLDS. ALIMENTARY CANAL

– The following graphic description may be added:

In the earlier stages of development the embryo lies flat on the surface of the yolk, and is but imperfectly marked off from the rest of the blastoderm. Gradually, however, a crescentic depression is formed, which limits the head: The blastoderm is, as it were, tucked in *under the head*, which thus comes to project above the general surface of the germinal membrane. A similar tucking in soon takes place at the caudal extremity, and, a little later, on either side of the embryo. The embryo is thus surrounded by a kind of moat.

This moat grows deeper & deeper, *i.e.*, runs in further & further beneath the embryo, which comes to overhang it on all sides. The embryo is thus shaped somewhat like a canoe turned upside-down. The ends, and the sides of the middle portion of this canoe, are, so to speak, decked in by the tucking in of the blastoderm; the centre of the under surface—the "well," or undecked portion of the canoe—presents a wide opening, by which the body cavity of the embryo (to continue the comparison) communicates with the cavity of the yolk-sac.

Further tucking in diminishes the size of this communication, and reduces it finally to a minute canal contained in a delicate hollow pedicle.

The portion of the yolk-sac included in the body-cavity forms the *alimentary canal*, which is first closed at both ends.—*(Slightly altered from Foster & Balfour).*

THE APPENDAGES of the EMBRYO

Are the umbilical vesicle, amnion, allantois, chorion and placenta. They develop simultaneously or nearly so.

UMBILICAL VESICLE

Is the lower & larger part of the blastodermic vesicle or yolk sac, which is separated at the umbilicus from that part, which has been enclosed in the abdominal cavity by the bending downwards and the curving towards each other of the ventral plates of the embryo. It is the source from which nutriment is first derived for the embryo.

It communicates for a time by a gradually narrowing canal, the vitelline duct, with the portion of the yolk sac, which is enclosed in the abdominal cavity.

The vessels which are early developed in the area vasculosa of the middle germinal layer, are soon joined by the vitelline or omphalo-mesenteric arteries, which then spread out on the umbilical vesicle, and even, in the case of birds and reptiles, project their twigs into its interior; the corresponding veins absorb, and convey to the embryo, the dissolved nutrient material of the yolk. These vessels are also the media of gaseous interchanges between the embryo and the other fluids of the ovum.

In birds and reptiles the umbilical vesicle is gradually drawn into the abdomen, its remains frequently persisting for a time as the vitelline cœcum, a short blind sac connected with the small intestine. In mammalia, amphibia & fishes it is much more transitory, but traces of it can generally be found at birth among the elements of the umbilical cord.

THE AMNION

Appears as soon as the extremities & sides of the embryo begin to bend downwards and inwards towards the centre of the ovum, and towards each other. It is formed by the rising up round the embryo, in the shape of a circular fold, the amniotic fold, of the portion of the external layer and somatopleure, which surround the area germinativa.

This fold is most marked at first over the head, or cephalic flexure, then over the caudal extremity of the embryo; it appears lastly over the laminæ ventrales.

Its edges arch over the dorsum of the embryo, meet, and unite.

The double layer of membrane becomes absorbed at the point of coalescence of the edges of the amniotic fold. The two layers of the fold are thus separated, the embryo being separated at the same time from the outer membrane of the ovum.

The inner layer of the amniotic fold now bounds with that portion of the outer layer of the germinal membrane, which covers the dorsum of the embryo and forms the epithelial coating of its integument, a closed sac, the amnion.

Fluid is secreted both within, and externally to, the cavity of the amnion; the outer layer of the amniotic fold, which is sometimes called the false amnion, is thus pressed against the vitelline membrane with which it soon becomes blended.

The amnion, when fully developed, is very similar to a serous membrane, and may be described as presenting an inner or visceral layer, and an outer or parietal layer.

These two layers are first in contact; but the serous fluid, or liquor amnii, secreted within the cavity of the amnion separates them, and the whole amnion becomes distended & enlarged.

The visceral layer of the amnion curves downwards & inwards with the extremities and laminæ ventrales of the embryo, and at last surrounds both the whole embryo (forming the epithelial layer of its integument) and the vitelline duct, and, when it is formed, the umbilical cord.

The parietal layer of the amnion reaches in time the surface of the ovum and finally lines the whole surface of the allantois, after this latter has spread out upon, and has become blended with, the false amnion & the vitelline membrane.

The parietal & visceral layers of the amnion are now continuous with each other over the placenta and the point of attachment to the placenta of the umbilical cord.

The amnion is formed at first of a thin structureless basement membrane lined with a delicate squamous epithelium; subsequently it contains a few fusiform cells.

The liquor amnii consists of water holding in solution from 1 to 3 per cent. of solid matter composed of albumen, urea and uric acid, allantoin & other extractives, sebaceous matter, epidermic scales & minute hairs thrown off from the embryo, and salts, such as lactate of soda and sulphate & phosphate of lime.

Note – The space between the amnion proper & the false amnion is continuous with that between the somatopleure & the splanchnopleure, *i.e.*, with the pleuro-peritoneal cavity.

THE ALLANTOIS

Is the medium by which the vessels of the second fœtal circulation become connected with the maternal structures, and the organ which serves the purposes of respiration & nutrition during the second part of fœtal life.

It appears as a small mass of nucleated cells on the under surface of the embryo near its caudal extremity, and is derived from that part of the middle & inner layers of the area germinativa which is to form the abdominal viscera.

It develops simultaneously with the intestinal canal, and is soon transformed into a hollow vascular protrusion of the anterior intestinal wall.

It then emerges from the abdominal cavity of the embryo along the caudal aspect of the vitelline duct & between the folds of the amnion which surround the pedicle of the now decreasing umbilical vesicle. It carries with it the vessels of the second fœtal circulation, or umbilical vessels.

The progressive closure of the umbilicus now divivides it into extra & intra-fœtal portions.

EXTRA-FŒTAL PORTION — Expands into a rapidly growing sac or bag.

When it meets the outer wall of the ovum (which is now formed by the vitelline membrane blended with the peripheral portion of the blastodermic vesicle or false amnion), it flattens out, and its walls become applied one against the other, so as to form a double disk-shaped membrane.

It then spreads over the outer wall of the ovum forming the endochorion.

The vessels of the inner or deep layer of the endochorion disappear, those of outer or superficial layer enlarge and become more and more numerous, and, in the case of the mammalian ovum, penetrate into the villi of the now developed chorion, forming the fœtal part of the placenta.

INTRA-FŒTAL PORTION — First forms part of the cloaca, or common outlet of the digestive, urinary & reproductive tracts. It is subsequently separated from the intestinal canal by a transverse septum, the perinæum. It then forms part of the urogenital sinus, which sinus forms the urinary bladder, and is finally modified inferiorly according to sex, while superiorly it contracts into a fibrous cord, the urachus.

THE CHORION

Is the *outer membrane of the fully evolved impregnated ovum.* — Let us trace its development.

The first covering of the ovum was the *vitelline membrane.* —

The germinal or *blastodermic membrane* appeared on the inner surface of this membrane directly after the segmentation of the yolk. — This blastodermic membrane divided into *three layers* in the extent of the area germinativa. The *two inner* ones formed the *embryo & the umbilical vesicle.* The *outer one* † rose up around the embryo in the shape of a circular fold or hollow process, the amniotic fold, and formed on the one hand the *amnion proper*, on the other hand the *false amnion.* This false amnion became blended with the vitelline membrane.

The outer membrane of the ovum is now formed *externally* by the *vitelline membrane*, *internally* by the *false amnion.*

The *allantois* now emerges from the embryo. It pushes its way between the folds of the amnion proper, which surround the pedicle of the decreasing umbilical vesicle, and spreads out *between* the *amnion proper* & the *false amnion*, with the latter of which it soon becomes blended.

The outer membrane of the ovum is *now* the *chorion.*

The *recently formed chorion* consists therefore from without inwards of the *vitelline membrane*, the *false amnion* & the *allantois.*

The *vitelline membrane & the false amnion* soon *disappear* for the former never was a vascular structure, and the latter ceased to have any vessels of its own as soon as it became separated from the portion of the blastodermic vesicle which formed the amnion proper.

The *definite chorion* is soon formed therefore by the *allantois only.*

(†with the peripheral portion of the somatopleure.)

P.

CHANGES in the OUTER MEMBRANE of the OVUM.

The *villi* begin to appear all over the ovum *as soon as the ovum enters the uterus* and the allantois emerges from the embryo.

They are at first but *minute structureless projections* of the vitelline membrane, but when the allantois has reached the surface of the ovum, allantoic vessels in the shape of *capillary loops* are *hollowed out into their substance.*

They soon *disappear* over the two-thirds of the surface of the ovum corresponding to the *dorsum* of the embryo.

Over the remaining third, that is to say over the *site* of the *future placenta,* they *divide and ramify* by a process of budding or sprouting, and soon consist of a narrow stem or pedicle giving off a multitude of secondary & tertiary branches of varying size & figure, all of which contain a capillary loop.

The *vitelline membrane* & the *false amnion* having *disappeared,* as above explained, the persistent *villi* are soon *formed* by the *allantois only.* They are then properly the villi of the chorion.

The tufted villi of the chorion *dip into* the *substance of the decidua*, and go on increasing in size till they finally *constitute* the *fœtal part of the placenta.*

THE DECIDUA

Is the *mucous membrane of the body of the uterus altered through impregnation.*

Shortly after impregnation the mucous membrane of the uterus becomes *thick, soft* & *vascular.* Its *glands* greatly *increase* in size, and *pour out* abundantly into the cavity of the uterus a special *albuminous fluid* rich in nucleated cells and destined to be absorbed by the villi of the ovum.

When the *ovum* emerges from the Fallopian tube into the cavity of the uterus, it first floats in this fluid.

It then becomes *imbedded in the decidua.*

The decidua *now divides into* three portions :

The DECIDUA REFLEXA *rises up round* the *ovum* and gradually *incloses it in a small mucous cavity* which communicates for a time with the general cavity of the uterus by a minute opening, the decidual umbilicus.

The DECIDUA SEROTINA is the portion of the decidua comprised *between* the *ovum* & the *wall of the uterus.* It soon *develops into* the *maternal part of the placenta.*

The DECIDUA VERA is the portion of the decidua which *lines the general cavity of the uterus.*

As the ovum increases in size the *decidua reflexa* & the decidua *vera* gradually *come in contact,* and *unite* so as to form one membrane.

THE PLACENTA & UMBILICAL CORD.

The placenta is a disc-shaped thickening of the membranes of the ovum adherent to the uterus usually at its upper part.

Its free or fœtal surface gives attachment to the umbilical cord usually near its centre, and presents the prominent diverging & converging branches of the umbilical arteries & vein. It is covered by the parietal layer of the amnion.

Its uterine surface, after it has become detached in parturition, is shaggy or velvety in appearance, and presents the vascular tufts or villi of the chorion.

The placenta is formed by the interlacing of the vessels of the chorion & of the decidua serotina.

On the one hand the villi of the chorion with their allantoic vessels dip into, and ramify within, the substance of the decidua serotina.

On the other hand the vessels of the decidua serotina multiply & enlarge to an almost incredible extent. They at first surround the villi with rich capillary networks, but dilating and fusing with each other, they soon lose entirely their capillary character, and are transformed into real sinuses. These sinuses are first developed towards the deep or uterine surface of the decidua, where they communicate with the vessels of the uterus by large and obliquely disposed openings; they grow upwards, and insinuate themselves between the branches of every one of the villi of the chorion.

All other structures but vessels have now disappeared from the placenta, so excessive is the vascular development: — The allantoic capillary loop was surrounded by the structures of the villus, viz., a layer of cells & basement membrane. The decidual capillaries were surrounded by the cellular structures of the hypertrophied decidua. — In the fully developed placenta the vessels of the fœtus literally dip into the maternal sinuses, a single membrane, the blended walls of the fœtal & maternal vessels, intervening between the two vascular systems.

The umbilical cord extends usually from the centre of the free surface of the placenta to the fœtal umbilicus.

It consists of two umbilical arteries & one umbilical vein, which are embedded in soft mucous connective tissue, the modified remains of the allantois, and surrounded by a tubular process of the amnion. The vestiges of the umbilical vesicle with its vitelline duct & omphalo-mesenteric vessels may sometimes be discovered among the structures of the cord.

APPENDIX

TO THE

GENERAL DEVELOPMENT OF THE EMBRYO.

Germinal Vesicle, Segmentation Granules, Blastides, Embryo-Cell.

The following additional facts now appear pretty clearly made out: –

Through the contraction of the yolk, the *germinal vesicle* is squeezed into the space between the yolk and the vitelline membrane either before, at the time of, or a little after, the escape of the ovum from the Graafian vesicle, *i.e.*, usually before, and therefore *independently of, fecundation.* Here the germinal vesicle *breaks down and disappears,* and its contents are dispersed.

Soon after fecundation there appear in the space above mentioned one, two, or three small hyaline and highly refracting spherules, sometimes called *segmentation granules.* These remain visible during the early stages of segmentation, and then disappear. Their origin & destination are unknown.

The term *blastides* has been applied to the multiplying nuclei of the segmentation masses. But whether these blastides precede, or are the result of, each act of segmentation, and in what way they are related to each other, is still unknown. A serious doubt has therefore been raised respecting the statements which were made about the *embryo-cell.*

The Two Primitive Layers, & the Third or Intermediate Layer of the Blastoderm.

The upper or outer of the two primitive layers of the blastoderm is made up of small prismatic cells, closely packed, and presenting a large & distinct nucleus.

The lower or inner layer is made up of larger, more rounded, and more granular cells scattered, in reticular groups, the nuclei of which cells are less easily perceived. Subsequently these cells become a little more closely packed, and somewhat flattened.

The mode of formation of the middle layer is still a disputed point. Among the more modern views are the following: –

It is derived from the upper layer (Kölliker).

It is derived from the lower layer (Remak).

It is derived from both layers (His).

It is a product of the *secondary segmentation,* which takes place below the lower layer; and the larger cells thus formed migrate to their final position between the upper & lower layers by passing *round the margin of the lower layer* (Stricker, Klein, and most of the Embryologists of the Viennese School), by passing *through the lower layer* (a few of the Embryologists of the same School).

It is derived *partly* from cells included from the first between the two primitive layers, and *partly* from cells of new formation, as above explained (Balfour).

Directly after its formation, the middle layer begins to thicken by a process of cell-multiplication.

Secondary Segmentation.

This is a secondary process of cell formation which, at least in the meroblastic ovum, continues for a considerable time both around the margins of the primitively limited blastoderm, and beneath it, *i.e.*, between it and the food-yolk, in what is sometimes called the *sub-germinal cavity.* It is by this secondary segmentation that the blastoderm of the meroblastic ovum is extended little by little all over the yolk (Balfour, Ray Lankester, Goette). Its supposed connection with the formation of the middle layer has just been described.

Partial Segmentation of Unfecundated Ova.

Segmentation is *not absolutely confined to fecundated ova.* But in unfecundated ova, especially in those of the higher vertebrates, the process is irregular and imperfect, and never results in the formation of a continuous blastoderm. This attempt at a segmentation raises however the question, whether the process is originated by the rupture of the germinal vesicle and the dispersion of its contents.

Primitive Trace or Groove.

From the recent researches of Balfour & Hensen it appears desirable to make a distinction between the primitive *trace* and the primitive *groove*.

The primitive *trace* is a mesial *thickening* of the epiblast & mesoblast, which precedes the appearance of the primitive *groove*.

It would further appear that the *primitive* groove is partially replaced, as follows, by another groove, the *medullary groove*, to which the current statements with reference to the primitive groove more accurately apply: – The primitive groove appears only in the *narrow posterior part* of the area pellucida, and it soon becomes shallow and faint in outline. In the broad anterior part of the area, in front of the primitive groove, and in the line of its anterior prolongation, there then appears this other groove, the *medullary groove*. This medullary groove extends itself backwards *into* the *primitive* groove, which it expands, dilates, and deepens.

Chorda Dorsalis

– For further particulars see page 172.

Walls of the Umbilical Vesicle.

After the complete development of the three layers of the blastoderm, the walls of the umbilical vesicle are formed by all these three layers. They remain so formed in amphibia & fishes, which have neither amnion nor allantois.

In reptiles, birds, & mammals, both the production of the amnion with the dependent pleuro-peritoneal space, and also subsequently the expansion of the Allantois, entirely separate the epiblast and the outer half of the mesoblast (Somatopleure) from the inner half of the same (Sphanchnopleure) & from the hypoblast. The sphanchnopleure & the hypoblast remain therefore *alone* as the *permanent* constituents of the wall of the yolk-sac. Through these, the wall of the yolk-sac is continuous with the wall of the intestine.

Amnion & Allantois.

It is through the mesoblastic elements which they contain that the two are both vascular & contractile. With regard to the false amnion, however, its vascularity ceases—as does also, necessarily, its muscularity—at its point of separation from the true amnion.

It is the outer layer of the true amnion, and the outer layer of the allantois, *i.e.*, the layers by which they come in contact, that are vascular & contractile.

In the case of the allantois, and especially in man, the degree of expansion of the inner or epithelial layer, and the degree of expansion of the outer or vascular layer, are not co-equal. The sac formed by the inner or epithelial layer—that which receives the fluid secreted by the temporary & by the permanent kidnies—ceases to expand as soon as the allantois as a whole has reached the outer wall of the ovum. It is only the outer layer of the allantois, that extends over the ovum and enters into the formation of the chorion & placenta.

The space between the amnion proper & the false amnion is continuous with that between the somatopleure & the spanchnopleure, *i.e.*, with the pleuro-peritoneal cavity.

Villi,—Origin of the Chorion.

From Kölliker's investigations it would appear that the simple villi are from the first, or at least from a very early date, both tubular in form and cellular in structure, and that they are derived therefore from the epiblast, and not from the vitelline membrane, which is structureless. Hence it would seem that the false amnion does not disappear from off the surface of the allantois, but that, on the contrary, it combines with it, and enters with it into the structure of the chorion. The chorion contains, therefore, both epiblastic & mesoblastic elements.

Placenta.

The uterine blood-passages, or sinuses, are irregular spaces into which the maternal blood is poured directly by numerous small coiled arteries: – fluid injected into the uterine arteries at once distends the sinuses, and everywhere surrounds the villi. The large & obliquely disposed veins, or *utero-placental veins*, by which the blood returns from the placenta, are most abundant towards the circumference of the placenta, where they blend, in fact, into the so-called circular vein, or circular sinus.

Synopsis of the Evolution of the Extra-Fœtal Portion of the Blastoderm.

1 – The Epiblast forms the *outer layer of the yolk sac*, the outer layer of the outer fold and the inner layer of the inner fold of the amniotic process, – therefore the *inner layer of the true amnion*, when the latter has become separated from the false amnion, – and probably also the *outer layer of the chorion* (V. Above).

2 – The Hypoblast forms the *inner layer of the yolk sac & umbilical vesicle*, and the *inner layer of the allantois.*

3 – The Mesoblast forms the *middle* or *vascular layer* of the *yolk sac* (This layer is the same as what becomes the *outer layer of the umbilical vesicle*, when the latter vesicle becomes separated from the outer wall of the ovum); the *outer or vascular layers of the amnion & allantois;* the *vascular layer of the chorion* (This layer is probably the inner layer, the outer layer being formed by the epiblast (V. Above); the *fœtal portion of the placenta.*

DEVELOPMENT OF THE ORGANS.

DEVELOPMENT of the ORGANS.—1st Tablet.

Is the result of the evolution of the fœtal portion of the three layers of the blastoderm.

Of this evolution, two views are taken which differ as follows in respect of the *pharynx, œsophagus, and respiratory tract,* namely, as regards (1)–the *source* from which their *epithelial lining* is derived (Vide below), and (2)–their *connection* with the *remainder of the alimentary canal* (Vide Next Tablet).

THE OLDER VIEW:-

The upper, or outer layer, or epiblast, gives rise to

Epidermis & its appendages;
Cerebro-spinal nerve-centres, and essential parts of the ear, eye, & nose;
Epithelium of MOUTH, NARES, PHARYNX, ŒSOPHAGUS, & RESPIRATORY TRACT.

The under, or inner layer, or hypoblast, gives rise to

Epithelium of ABDOMINAL PORTION *of alimentary canal, urinary bladder, and glands which open into these parts.*

The middle, or vascular layer, or mesoblast, gives rise to

All the rest of the body.

THE MORE MODERN VIEW:-

The upper, or outer layer, or epiblast gives rise to

Epidermis & its appendages;
Cerebro-spinal nerve-centres, and essential parts of the ear, eye, & nose.
Epithelium of MOUTH & NARES.

The under, or inner layer, or hypoblast, gives rise to

Epithelium of WHOLE *alimentary canal* (the mouth excepted), RESPIRATORY TRACT, *urinary bladder, and glands which open into these parts.*

The middle, or vascular layer, or mesoblast, gives rise to

All the rest of the body.

DEVELOPMENT of the ORGANS.—2nd Tablet.

THE TWO VIEWS CONTINUED.

According to the older view, the epithelium of the pharynx, œsophagus, & respiratory tract is derived, in common with that of the mouth & nose, from the *epiblast;* according to the more modern view, the epithelium of these parts is derived, in common with that of the whole alimentary canal, except the mouth, from the *hypoblast.* And these two views regarding the epithelium of these parts are in harmony with the two corresponding views regarding the connexion of the other strata of the walls of these parts with the remainder of the alimentary canal, *i.e.*, regarding the portion of the mesoblast from which these other strata are derived: – According to the older view, the pharynx, œsophagus, and respiratory tract are formed *as a prolongation backwards of the cavity of the mouth;* according to the more modern view, they are a part of the *intestinal* portion of the alimentary canal.

REMARKS on the TWO VIEWS.

Two things are clear: –

1. That the *abdominal, i.e., intestinal portion* of the alimentary canal results from the involution of a portion of *yolk-sac,* and that it is derived therefore from the *hypoblast* and from the *splanchnopleure division of the mesoblast;*

2. That the *Cephalic Portion* of the alimentary canal, *i.e., The Mouth,* is formed independently, as an involution of the epiblast (integument of the face).

But the question may still be asked, Whence are derived the intermediate portions of the alimentary canal, *i.e.*, the *Thoracic or Œsophageal,* and the *Cervical or Pharyngeal?* Are they a part of the *primitive* alimentary, or *intestinal,* canal, *i.e.*, a part of the involuted yolk-sac? Or do they result from a subsequent prolongation forwards of the *intestinal canal?* Or do they result from a prolongation backwards of the *cavity of the mouth?* And, since the *Respiratory Tract* is developed as an involution of the anterior wall of the pharynx, the further question may be asked, From whence is the *Respiratory Tract* derived, from the intestinal canal, or from the mouth? From which primary source is the epithelium of these parts derived, from the *hypoblast,* or from the *epiblast?*

Notwithstanding the high authority of Messrs. Foster & Balfour, the Author supported in his first edition the view taken by his old Masters, Coste & Longet, *i.e.*, the one given in the foregoing Tablet under the heading "The Older View."

He did so for the following reasons: – (1) There being neither thorax nor neck in the early condition of the embryo, he did not see how the œsophagus & pharynx could be formed at so early a date as they apparently must be, if the more modern view be correct. (2) The sudden transition at the cardia from the thick, opaque, & squamous epithelium of the pharynx & œsophagus to the thin, soft, transparent, and columnar epithelium of the remainder of the alimentary canal, appeared to him confirmative evidence of the view of the different origin of these parts, as did also the investment of the latter parts by serous membrane as opposed to the non-investment of the former, and also the formation in front of these former parts, and evidently from mesoblastic elements, of organs (heart, trachea, bronchi, large vessels, thymus gland) to which nothing corresponds in front of the latter parts.

Desiring, however, that this work should be marked by the record of established facts rather than by argumentation, and further recognising the import of the better description of the peritoneum as given of late by Messrs. Foster & Balfour, and also, on the other hand, the undesirability of resting any definite significance on the mere circumstance of a change of epithelium, the Author here drops the question in dispute, and respectfully submits his former & still somewhat favourite views to those of his more competent seniors: – *The following Tablets have been altered to the above effect.*

DEVELOPMENT of the NERVE-CENTRES.

DEVELOPMENT of the BRAIN.

The cephalic end of the primitive tube of nervous substance (V. General Development of the Embryo) soon presents three hollow dilatations or vesicles, the anterior, middle & posterior primary cerebral vesicles, of which the middle one is the largest.

These three dilatations are at first in a line one behind the other.

As the extremities of the embryo curve downwards towards the centre of the ovum, so does the cerebro-spinal axis, the curve of the cephalic end being most marked between the anterior & the middle cerebral vesicles and between the future cord & the posterior cerebral vesicle, in which latter situation it gives rise to the cervical tuberosity.

Posterior Cerebral Vesicle – Soon becomes larger than the middle one, and forms in its posterior part, or metencephalon, the medulla oblongata, and in its anterior part, or epencephalon, the cerebellum, the pons & the cerebellar peduncles.

The portion of the primitive nervous tube which forms the medulla oblongata does not close behind, the margins of the aperture forming the diverging restiform bodies and exposing the floor of the 4th ventricle.

The cerebellum is at first a thin transverse plate which forms the median lobe or vermiform process only. The lateral hemispheres appear subsequently in mammalia & birds; they do not appear at all in reptiles & fishes.

Middle Cerebral Vesicle – Grows more slowly than the others, & is soon the smallest. On its dorsal aspect it forms the corpora quadrigemina, which remain permanently hollow in birds. The central cavity comprised between these parts shrinks into the aqueduct of Sylvius. – On its under surface it develops into the peduncles of the cerebrum.

Anterior Cerebral Vesicle – Is at first smaller though broader than the middle vesicle, but it soon becomes by far the largest of the three. In its posterior part, or diencephalon, it forms the optic thalami, which are separated by a longitudinal groove, the future 3rd ventricle, and from the outer surface of which two flask-shaped outgrowths, the primary optic vesicles, are seen to arise. In its anterior part, or prosencephalon, it forms the corpora striata, the cerebral hemispheres with the commissural fibres of the corpus callosum, the fornix, and the septum lucidum.

The hemispheres develop rapidly from before backwards, overlapping the optic thalami and, in the higher vertebrata, the corpora quadrigemina & the cerebellum. At first they are thin & smooth and enclose a large cavity, the lateral ventricle, but this cavity is soon diminished by the thickening of its walls, which walls become divided externally by primary fissures into lobes and by sulci into convolutions.

The transverse commissural fibres of the corpus callosum multiply and extend from before backwards, as do the hemispheres, and close in the lateral ventricles.

From the under surface of each anterior lobe a hollow process passes forwards, and forms the olfactory lobes which remain hollow in some animals.

DEVELOPMENT of the SPINAL CORD.

The central and caudal portions of the cerebro-spinal axis form the spinal cord. This consists at first of a central canal bounded by a surrounding layer of nucleated cells. The most central of these cells form an epithelial lining, the ependyma; the more peripheral ones develop chiefly into the central grey substance, the white substance being formed subsequently. – The cord extends at first throughout the whole vertebral canal, but it grows less rapidly than the canal itself, wherefore, the roots of the spinal nerves being joined to the cord, the cauda equina is progressively formed. The central canal of the cord persists through life, but its diameter is reduced to 1-100th of an inch.

Brain & Cord.

One further point of interest should be noted with respect to both brain and cord: – The primitive tube of nervous substance appears to result from the involution, not of the *primitive* groove only, as was believed up till very lately, but rather of the *primitive & medullary* grooves fused into one (Vide Appendix, page 127, 128, 129A.)

Cord.

The morphological changes both of the central canal and of the central grey & peripheral white substances, and, on the other hand, the mode of formation of the roots of the nerves, ganglia, and commissures, have recently been investigated, the former subjects by Lockhart Clarke, and the latter by Balfour. The following are the results of these investigations : –

The *grey matter* thickens greatly in either lateral half of the cord, and compresses the central canal so that the latter assumes the form of an antero-posterior slit. The grey masses of either side then unite opposite the centre of the canal, the canal being thus divided into an anterior part, which becomes the *permanent central canal*, and a posterior part, which latter, receiving a septum of connective tissue, becomes the *posterior median fissure*.

The *white substance*, which is formed subsequently, accumulates mainly at first in the situation of the anterior columns; and, these columns coming to project more & more, a groove, the gradually deepening *anterior* median fissure, becomes formed between them. – Towards the caudal extremity, the central canal remains open behind for a considerable time, forming a lozenge-shaped dilatation, the *rhomboidal sinus*, which is persistent in birds.

It was generally admitted up till very lately (1) that the *spinal ganglia & the roots of the spinal nerves* are developed *independently of the cord*, from the same parts as, and just in front of, the lamina and processes of the vertebra and the posterior end of the rib formed immediately behind them, *i.e.*, from the *anterior & outer part of a re-segmented protovertebra* (V. Skeletal Matrix, 2d & 3d Tablets); and (2) that they are *subsequently joined to the cord*. Balfour's researches in the Elasmo-branch fishes (Scillium & Torpedo) appear however to show that these parts are developed as *involuted outgrowths of the epiblast of the neural canal*. The posterior outgrowth, that which forms the posterior root & the ganglion, is the first formed; it springs from near the posterior median fissure, but its point of attachment to the cord subsequently moves outwards. The anterior outgrowth springs from near the place of its permanent attachment. The two outgrowths join one with the other beyond the situation of the ganglion.

The fibres of the roots pass into and through the grey substance, and, crossing to the opposite side in front of the central canal, differentiate the *anterior or white commissure* from the *posterior or grey one*.

Dr. Allen Thomson's Description of the Development of the Face.

The History of the Development of the Face & Neck is always more or less complicated by the different names which are given to each of the several arches, and by the different modes adopted for counting them. A parallel between the description given in the Tablets and that given by Prof. Allen Thomson in the 8th Edition of Quain's Anatomy (pages 738 to 740) will, it is believed, facilitate the study of this important subject in the above important and most remarkable treatise.

In Dr. Thomson's description, the frontal process and the four arches are first divided into *two preoral, and four postoral* arches, bars, or plates; the total number, *six*, being obtained by counting the upper & lower processes of our 1st arch separately,– the upper process as belonging to the *preoral* set, the lower one to the *postoral* set. The first or superior branchial cleft, or maxillary cleft, is further separated from the others as the *great buccal aperture;* this reduces the number of the *clefts* between the arches to *three*, instead of *four.*

The two *preoral* arches, *i.e.*, our frontal process & the upper of the two processes of our first arch, are divided into deep & superficial parts.

In its deeper part, the frontal process is designated the *premaxillary process*, and its connection is described with the *Trabeculæ Basis Cranii of Rathke* (V. Development of the Bones). In its more superficial part, this process is designated the *fronto-nasal plate*, and the two offsets for the alæ nasi are called the *external nasal processes*, or the *lateral or external nasal plates.*

In its deeper part, the superior process of our 1st arch is designated the *pterygo-palatine arch.* In its more superficial part it is called the *superior maxillary process*, or the *maxillary plate.*

Each of these two processes being then referred to as a whole, the terms used are respectively the *middle & external nasal*, and the *superior maxillary;* the upper & deeper parts of the frontal process, or the trabeculæ basis cranii, being further referred to as the *subcranial plates.*

The first of the *postoral set* of arches, bars, or plates, is the lower process of our 1st arch, which is called the *mandibular*, or *inferior maxillary*, or *first postoral arch.* The cleft behind this, *i.e.*, our *second* branchial cleft, is called the *first postoral cleft*, or *tympano-Eustachian cleft or canal.*

Our second branchial arch similarly becomes the *second postoral bar*, further called the *second or Hyoid arch.* Similarly also does our *third* branchial cleft become the *second postoral cleft*, which is further designated as the *first true water passage.*

The arch behind this, *i.e.*, our third branchial arch, is the *third postoral arch*, or *thyro-hyoid arch*, which "corresponds with the *first true branchial arch* of amphibia & fishes." Our *fourth* branchial cleft becomes Dr. Thomson's *third postoral cleft.*

Our fourth arch is Dr. Thomson's *fourth postoral*, or *sub-hyoid*, or *cervical arch.* Finally Dr. Thomson's *fourth postoral cleft* is the slight notch below or behind the sub-hyoid arch, which, if designated numerically, would be our *fifth* branchial cleft.

DEVELOPMENT of the FACE & NECK.

The cephalic extremity of the embryo being greatly enlarged, a cavity, that of the mouth, is formed in its interior by the depression of the integument (epiblast) of the face. This depression first deepens through the projection forwards of the frontal or intermaxillary process and of the two divisions (superior maxillary & mandibular) of the first arch. It then opens into the pharynx, or upper extremity of the primitive alimentary canal, the opening forming the fauces.

FRONTAL or INTERMAXILLARY PROCESS & BRANCHIAL, VISCERAL or PHARYNGEAL ARCHES — The branchial, visceral or pharyngeal arches are the four processes into which the ventral plates break up in the cervico-facial region. They pass forwards from the upper part of the chorda dorsalis, and bend downwards & inwards towards each other. The frontal or intermaxillary process is a similar outgrowth which descends in the middle line from the front part of the cranium. These processes are separated by four fissures or clefts, the branchial clefts. (The term branchial is here misapplied, for it is only in fishes that branchiæ or gills are developed from these parts).

The frontal process forms the outer walls & the septum of the nasal fossæ, the central part of the upper lip & the intermaxillary bones. It is bifid inferiorly, but its two halves subsequently unite. Two offsets from its sides curl downwards and then inwards, and form the alæ nasi which encircle the anterior orifices of the nares.

The first pair of branchial arches give off two processes. One, the inferior, forms the lower jaw, the other, the superior, forms the upper jaw with the assistance of the frontal process.

The lower jaw developes much more quickly than the upper one, and its two halves are joined together, and, in man, are consolidated into a single piece before the three segments of the upper jaw have come into contact.

The upper jaw is formed by the junction, on either side of the face, of the frontal process with the superior offset of the upper branchial arch. The groove between these parts closes in front and forms the nasal duct.

The mouth and the nasal fossæ are therefore developed from the first or superior branchial cleft, sometimes called the maxillary cleft. The occasional non-union, on one side, of the frontal or intermaxillary process with the superior offset of the first branchial arch is the cause of the most common or lateral form of hare-lip; hare-lip may however be bilateral. The malformation may also be situated in the median line; it is then due to the non-union of the two intermaxillary bones and of the corresponding soft parts.

The tongue appears as a small tubercle behind the inferior process of the first branchial arch. From the posterior part of the *first branchial arch* are also developed the epiglottis & arytenoid cartilages, the palate bones & internal pterygoid plates and also Meckel's cartilage, which latter forms posteriorly the malleus & possibly also the incus, and then passes downwards to support the inferior maxilla during its ossification, but subsequently disappears in its anterior part.

The *second branchial cleft* forms the tympanum, the Eustachian tube, the external auditory canal & its appendages. The *second branchial arch* forms the stapes, and also in the neck the styloid process, the stylo-hyoid ligament & the lesser cornu of the hyoid bone.

The *third branchial cleft* closes up early and disappears. The *third branchial arch* gives origin to the body & the greater cornu of the hyhoid bone and to the upper half of the soft parts of the neck.

The *fourth branchial cleft* also closes up early & disappears. The *corresponding arch* forms the lower half of the soft parts of the neck.

DEVELOPMENT of the NASAL FOSSÆ.

The nasal fossæ appear as two *depressions of the integument of the upper & central part of the face*, which part is formed by the frontal or intermaxillary process, as explained in foregoing Tablet. As this process elongates, these fossæ reach little by little their permanent & more central position.

They are at first *blind pouches*, but they soon *communicate with the mouth & pharynx ;* from which, however, they are subsequently separated in part of the formation of the *palate.*

Their walls are at first of very simple structure: they are formed solely by the *mesoblastic elements* of the above mentioned process.

They become more complex, however, as these elements differentiate into the *structures described in connexion with the development of the skull.*

Thus, after a time: –

(1). The two fossæ are separated from each other by the mesial plate of cartilage & bone (cartilage of the septum, perpendicular plate of the ethmoid, & vomer) which plate results from the union of the two antero-lateral halves of the trabeculæ basis cranii of Rathke.

(2). Their lateral boundaries are formed from before backwards as follows: – *Anteriorly*, by the two lateral offshoots of the frontal process which form the alæ nasi; *More deeply*, by those lateral portions of the trabeculæ in which are developed the nasal, intermaxillary, lachrymal, & inferior turbinated bones, & the lateral mass of the ethmoid; *And deeper still* (and after the formation of the pharynx) by the portion of the upper process of the first branchial arch (or *second preoral* or *pterygo-palatine* arch of Dr. Thomson), in which are formed the superior maxillary & palate bones, and the internal pterygoid palate of the sphenoid.

(3). Their floor (horizontal plate of the palate bone, & palate process of the superior maxilla) is also formed from the foregoing process.

(4). Their roof (cribiform plate of the ethmoid) is formed from the trabeculæ basis cranii of Rathke.

Note – It is still uncertain whether the olfactory nerves are developed as *offshoots* from the *olfactory bulbs*, or whether they are formed from *peripheral mesoblastic elements*, as are all other nerves except the optic.

DEVELOPMENT of the EYE.—1st Tablet.

The eye is developed from the three following sources:—

Primary Optic Vesicle, & Optic Cup – Which form the *optic nerve*, the *retina*, & the *pigmentary layer of the choroid;*

Cuticle of the Face – Which forms the *lens*, and the *epithelium of the conjunctiva & cornea;*

Mesoblastic Elements intervening between & around the Above Mentioned Parts – Which elements form *all the other structures.*

ITS APPENDAGES – Are developed as follows:—

Eyelids – As two folds of integument, which rise up above & below the eyeball, and then adhere to each other till about the time of birth.

Lachrymal Canals, Lachrymal Sac, & Nasal Duct – As a persistent part of the fissure between the frontal or inter-maxillary process and the upper of the two processes given off by the first pair of branchial, visceral, or pharyngeal arches. (V. Development of the Face.)

DEVELOPMENT of the EYE.—2nd Tablet.

PRIMARY OPTIC VESICLE, & OPTIC CUP..... (or CUPS).

The primary optic vesicle is a flask-shaped outgrowth of that portion of the anterior cerebral vesicle which forms the optic thalamus.

Its pedicle becomes filled up with nervous substance, and forms the *optic nerve*, and, by joining with its fellow, the *optic commissure.*

As it expands, the primary optic vesicle comes in contact with the *lens* already formed in front of & a little below it, as hereafter explained.

The lens is frequently said to press upon the primary optic vesicle so as to (1) invaginate its lower & anterior half into its upper & posterior half, and thus (2) obliterate its cavity.

Whatever explanation be given of the change, the antero-inferior aspect of the primary optic vesicle comes to present a depression or cup, a gradually deepening depression or cup, the *optic cup* (Foster & Balfour); and the more this cup deepens, the more is the cavity of the primary optic vesicle encroached upon.

Finally the walls of the optic cup come in contact with the posterior & upper walls of the primary optic vesicle.

Then, on the one hand, the cavity of the primary optic vesicle has ceased to exist, and, on the other hand, there are really two cups, of which the first one, the lower or smaller one, the *optic cup*, is included within the other, upper, or larger one.

The lower or smaller cup, or optic cup, thickens considerably, and becomes the *retina.*

The upper or larger cup remains relatively thin, and forms the *pigmentary layer of the choroid.*

The brims of the two cups are continuous one with the other. They form a circle or ring which clenches the upper & lateral portions of the circumference of the lens.

The lower & central portion of the circumference of the lens is not clenched. And here the ring presents for a time, a notch, fissure, or cleft, the *choroidal cleft.*

This cleft passes backwards towards, and probably even into, the optic nerve; as pigment is deposited all around it, the cleft itself comes to appear as a white line on a dark back-ground.

It is through this cleft, that, as hereafter explained, mesoblastic elements penetrate between retina & the lens to form the vitreous body with the hyaloid membrane & the zonula of Zinn, the posterior half of the capsulo-cupillary membrane with the ciliary processes, and probably also the posterior lamella of the capsule of the lens; – also, probably, in mammals (Leiberkühn), the arteria centralis retinæ; this artery resulting from the intrusion of mesoblastic elements far back into the optic nerve by means of a prolongating backwards of the choroidal cleft.

Normally the choroidal cleft closes up early. When it persists, it gives rise to the malformation termed *coloboma.*

Notes.

The optic cup has frequently been called the *secondary optic vesicle.*

The *pigmentary layer of the choroid* is now usually described as the *outer layer of the retina.*

CUTICLE OF THE FACE

Becomes thickened in its deeper layers, depressed, and finally invaginated so as to form a closed sac or hollow ball. This closed sac or hollow ball becomes the *lens* (V. Next Tablet).

MESOBLASTIC ELEMENTS

Intervene in *three situations:* –

Between the optic cup & the lens, to form the vitreous body with the hyaloid membrane & the zonula of Zinn, the posterior half of the capsulo-pupillary membrane with the ciliary processes, and probably also the posterior lamella of the capsule of the lens; – also, probably, in mammals (Lierberkühn), the arteria centralis retinæ; this artery resulting from the intrusion of mesoblastic elements far back into the optic nerve by means of a prolongation backwards of the choroidal cleft.

Between the lens & the integument of the face, to form the cornea, the iris, the anterior half of the capsulo-pupiliary membrane, and probably also the anterior lamella of the capsule & the suspensory ligament of the lens.

Around the eyeball, to form the *lamina fusca*, the venous & capillary layers of the choroid, the ciliary muscle, the sclerotic with the muscles attached to the latter, & the conjunctiva.

DEVELOPMENT of the EYE.—3rd Tablet.

Details of the Development of the Lens.

The development of the lens from the closed sac or hollow ball of cuticle already described takes place as follows:

Except towards the periphery of the organ, the cells derived from the superficial or corneous layers of the cuticle undergo but little change: – they remain as a single stratum of flattened, polygonal, nucleated cells lying beneath the anterior lamella of the capsule. Here they form the anterior boundary of the small cavity of the lens, which cavity is soon obliterated.

Towards the periphery of the lens, these cells elongate slightly, and pass little by little into the stratum of proper lens-fibres.

These proper lens-fibres are formed by the elongation, and by the rising up in the vertical direction, of the mass of cells from the deep layer of the cuticle which line the lateral & posterior walls of the lens cavity.

The more central of these cells elongate and rise up first, then comes the turn of the more, and finally that of the most, peripheral ones, – which latter elongate but slightly, and pass little by little into the stratum of flattened, polygonal, nucleated cells, above described as derived from the corneal layer.

As the cells elongate and rise up to become fibres, they carry forwards their nuclei. These nuclei, at first everywhere very distinct, soon cease to be apparent except towards the periphery, where they constitute the *nuclear zone.* This zone, first situated towards the posterior aspect of the lens, advances slowly therefore towards the anterior aspect.

Now appear both the radiating lines separating the segments of the superimposed laminæ of the lens, and the anterior & posterior poles of the organ; both these radiating lines & the poles are made up of granular collections of the cells, to the margins of which collections the extremities of the lens-fibres are soon clearly traceable.

Note. – The *capsulo-pupillary membrane* is a delicate vascular investment of the lens, supplied on its posterior aspect by a branch of the *arteria centralis retinæ.* Its fore part adheres to the margins of the pupil, and forms the *pupillary membrane.* Both structures disappear when the anterior or aqueous chamber begins to expand, *i.e.,* a little before birth.

DEVELOPMENT of the EAR.—1st Tablet.

The several parts of the ear are developed from the following sources, respectively : -

INTERNAL EAR - From *three sources*, as follows : -

Membranous Labyrinth (Minus its Outer Wall) - From the *primary auditory vesicle*, which latter is derived from the *cuticle of the side of the head.*

Osseous Labyrinth - From the *primitive cartilage* of the base of the skull. - The *modiolus* & the *lamina spiralis* appear, however, to be developed *in membrane* (Kölliker).

Its Periosteum, Space for the Perilymph, Scalæ Vestibuli & Tympani of the Cochlea, & Outer Wall of the Membranous Labyrinth - From connective tissue intervening between the vesicle & the cartilage.

TYMPANUM, & EXTERNAL AUDITORY CANAL - As a persistent part of the *second branchial cleft*, - or of the *first postoral cleft*, according to Dr. Allen Thomson's mode of counting the cervical arches & clefts.

MEMBRANA TYMPANI, OSSICLES, & PINNA - From the *two first cervical arches*, - or, according to Dr. Thomson's mode of counting, from *the two first postoral arches.*

The Malleus is developed in the *first cervical or first postoral arch* from the proximal part of Meckel's cartilage. The Pinna, the Stapes, & Stapedius Muscle, and probably also the Incus, are developed in the back part of the *second cervical or second postoral arch.*

DEVELOPMENT of the EAR.—2nd Tablet.

DETAILS of the DEVELOPMENT of the INTERNAL EAR, from the

Primary Auditory Vesicle – The history of this vesicle is as follows: –

A depression or pit appears very early on the side of the head.

It is soon covered in, and transformed into a closed sac, the *primary auditory vesicle.*

This vesicle sinks in, or recedes, towards the back part of the 3rd cerebral vesicle, or future medulla oblongata, with which it becomes connected by means of the auditory nerve.

The primary auditory vesicle now develops as follows into the membranous labyrinth: –

Its central part forms the *vestibule.*

The essential part of cochlea, the *canalis membranacea,* is formed by a prolongation of the vesicle downwards & forwards, which prolongation is first straight, but afterwards curls upwards upon itself. – Differentiations in the epithelium of the floor of the canalis membranacea give rise to *rods of Corti, etc.*

The *semicircular canals* appear externally as linear projections, internally as furrows, which furrows are transformed into canals by the bending in of walls of the vesicle under them.

The *Aqueductus Vestibuli* is formed by a prolongation upwards & backwards. – This aqueduct is permanent in the lower vertebrata.

Primitive Cartilage of the Base of the Skull.

The *periotic cartilage* is formed from the lateral portion of the *investing mass of Rathke* (V. Cartilaginous Skeleton).

Connective Tissue intervening between the Vesicle & the Cartilage.

This divides into three layers: –

The *outer layer* forms the *periosteum of the osseous labyrinth.*

The *inner layer* forms the *outer layer of the membranous labyrinth.*

The *middle layer* swells up into a gelatinous tissue, the meshes of which become wider & wider till at last the *whole space which ultimately contains perilymph,* – which space includes the *scalæ vestibuli & tympani* of the cochlea, – in left as a vacuity.

Notes – The auditory nerve appears to be developed from peripheral mesoblastic elements, not as an outgrowth from the nerve-centres. As the cochlea curls upon itself, so does also the gangliform extremity of the cochlear nerve, which latter becomes the *ganglion spirale.*

DEVELOPMENT of the HEART.—1st Tablet.

GENERAL VIEW.

The heart is developed from the splanchnopleure layer of the mesoblast, in front of the upper portion of the primitive alimentary canal.

It appears at first as an elongated mass of embryonic cells.

The liquefaction of the more central cells, or their separation from each other, transforms this mass into a straight longitudinal utricle or sac.

This sac is at first widest behind, and narrowest in front.

From its anterior or upper end an arterial trunk arises, the two terminal divisions of which trunk first curve backwards on either side of the pharynx & below the protovertebræ, and then join together to form the abdominal & thoracic portions of the aorta (V. Arterial System).

To its lower or posterior end a venous trunk is added, which receives the omphalo-mesenteric veins.

Its walls differentiate into fibro-mascular & epithelial layers, and its contents, – imperfectly formed blood, – are propelled forwards by alternating movements of systole & diastole.

The primitively straight tube now becomes elongated & bent open itself, and divided by two constrictions into three portions, *ventricular*, *auricular*, *&* *arterial bulb*. The *ventricular* portion bulges out, thickens greatly, and becomes more & more developed inferiorly. The *auricular* portion comes to lie above & behind the ventricular; its walls remain relatively thin; diverticula from its sides form the *appendices auriculæ*.

No further change takes place in *fishes*.

In reptiles, birds, mammalia & the human subject, a *septum* dividing the *auricular cavity* into two is developed partly from before backwards & partly from behind forwards; but it is not completed during fœtal life, an aperture remaining, the *foramen ovale*, through which a partial admixture takes place between the arterial & the venous blood.

In birds, mammalia, & the human subject, a *septum* dividing the *ventricular cavity* into two *commences* at the *apex* of the heart, extends upwards, and joins with the septum which divides the arterial bulb into aorta & pulmonary artery.

Notes.

As the abdominal & thoracic portions of the aorta are formed by the fusion of the two parallel & adjacent primitive vertebral arteries (See Arterial System), so also would it appear from the investigations of Kölliker & Hensen that the heart consisted *primitively* of two adjacent tubes each connected posteriorly with a vein and anteriorly with an artery, which tubes became united into one at an exceedingly early date.

In the cold-blooded pulmonated vertebrata *(reptiles & adult amphibia)* the ventricular cavity does not divide, except to a slight extent in Saurians. As regards the warm-blooded pulmonated vertebrata *(birds, mammalia, & the human subject)* the common auricular cavity presents the external appearance of being divided into two at a period antecedent to that of the partition of the ventricles. It would appear, however, that this is but an optical illusion due mainly to the projection of the auricular appendices, and that, in reality, the partition of the common ventricle precedes that of the common auricle.

DEVELOPMENT of the HEART,—2nd Tablet.

DETAILS OF THE PROCESS.

Division of the Common Auricular Cavity into Right Auricle & Left Auricle.

Takes place partly from before backwards, and partly from behind forwards.

A fold of the upper & anterior walls passes downwards & backwards to a little beyond the middle of the cavity. This fold leaves below & behind an oval deficiency, the *foramen ovale,* to the anterior margin of which the *Eustachian valve* soon becomes joined.

A fold of the posterior wall now projects forwards to the left of the foregoing. As it advances, this second fold meets the first one, adheres more & more to its free margin, and thus closes up the foramen ovale. Rarely however, at least during fœtal life, is the adhesion of the two folds complete, and the closure of the foramen perfect. A small aperture usually remains at the anterior part. But the posterior fold advancing *beyond* the free margin of the anterior one, a valvular arrangement is created, which prevents the passage of the blood from one auricle into the other.

Division of the Common Ventricular Cavity into Right Ventricle & Left Ventricle.

The interventricular septum appears a little to the right of the apex of the heart, in the shape of a *cleft,* when viewed from the exterior, in the shape of a *crescentic fold,* when viewed from the interior.

Externally, the cleft first grows deeper & deeper, and then becomes somewhat effaced.

Internally, the crescentic fold projects more & more towards the common auriculo-ventricular opening & the arterial bulb, and then joins with the septum which divides the cavity of the bulb into two.

Division of the Arterial Bulb into Aorta & Pulmonary Artery.

Is effected by the projection inwards, on the anterior & posterior aspects of the distal portion of the bulb, of two folds of its inner & middle coats only, – therefore *without the appearance of any external cleft.*

As soon as they are joined together, these folds pass downwards in a spiral manner towards the ventricular septum, with which they unite.

The lumen of the bulb is thus divided into two canals twisted round each other: The more anterior canal, *i.e.,* the *pulmonary artery,* becomes connected below with the right ventricle; above, it passes to the left of, and somewhat behind, the other canal, *i.e.,* the *aorta,* which becomes connected below with the left ventricle.

A splitting of the septum into two layers completely separates the two vessels, except as regards their common serous investment from the pericardium.

The distal extremities of the two canals become connected with the first & second cervical arches respectively, – or with the fifth & fourth cervical arches according to Dr. Allen Thomson's mode of counting these arches.

Formation of the Valves.

The *auriculo-ventricular valves* appear in the form of complete annular folds, which divide superiorly into their respective segments and break up inferiorly into the *chordæ tendineæ.* The *semilunar valves,* similarly formed, show early traces of their trifid division. The sinuses of Valsalva appear at a later date.

Note – The fœtal heart is larger, in proportion to the size of the body, than that of the adult; and its auricular portion is larger than the ventricular, first absolutely, then relatively. Up to near the time of birth, the walls of the right ventricle are as thick as those of the left one.

EMBRYONIC CIRCULATION

Consists of the circulation of the embryo proper, and of the collateral circulation of its two successive sets of nutritive & respiratory appendages, the umbilical vesicle on the one hand, and the allantois, chorion and placenta on the other.

COLLATERAL CIRCULATION of APPENDAGES of EMBRYO —

Presents two distinct & successive stages, the vitelline and the allantoic or placental.

VITELLINE CIRCULATION — Appears in the middle germinal layer of the blastodermic membrane at the same time as, but independently of, the vessels of the embryo proper, and constitutes the area vasculosa: – linear series of cells disposed in a radiating network become transformed, by central & peripheral differentiations, into a plexus of blood vessels, which plexus is bounded at its circumference by a circular venous vessel, the sinus terminalis.

This plexus becomes connected with the vessels of the embryo, first through numerous small vessels, and then through the vitelline or omphalo-mesenteric arteries & veins, which vessels emerge from or enter either side of the embryo; after a time the right omphalo-mesenteric artery & the right omphalo-mesenteric vein shrink & disappear, the vessels of the left side alone remaining.

The degree of extension, and the persistence, of the vitelline circulation vary in different animals with the size & duration of the umbilical vesicle. The vitelline circulation is transitory, unimportant, and probably mainly respiratory, in the mammalia; in birds, on the contrary, the vitelline vessels project twigs into the substance of the yolk, and persist up to the period of hatching, and even for some time afterwards until the whole of the contents of the yolk are absorbed.

ALLANTOIC, or PLACENTAL CIRCULATION — Appears with the allantois, which latter conveys the umbilical vessels towards the surface of the ovum.

The umbilical arteries are at first two small lateral branches of the aorta, which branches are however soon transformed by successive variations in the diameter of the vessels, first into the two terminal divisions of the aorta, or common iliacs, then into the internal iliacs, and finally into mere branches of the latter.

The umbilical veins open into the omphalo-mesenteric.

These vessels ramify in reptiles & birds on the outer surface of the allantois beneath the shell & shell-membrane, and form in the mammalia the vessels of the chorion, fœtal part of the placenta & umbilical cord; the right vein disappearing however before the completion of the placenta.

Note – The course of the blood in the *adult* fœtus is given, page 18.

Notes.

It is believed by some that the two *omphalo-mesenteric arteries* are primitively the continuation of the two primitive vertebrals, by the union of which the aorta is formed.

(The separate description of the *Collateral Circulation of the Embryo* will be found, it is believed, to simplify considerably the whole subject of *Fœtal Circulation*).

Dr. Allen Thomson's Description of the Cervical Arches.

It is believed that the following remarks will facilitate the study of the above subject as treated by Dr. Allen Thomson in the 8th Edition of Quain's Anatomy, pages 793 to 796.

1. – The two uppermost arches are such transitory structures that little positive information has yet been gained respecting them: Dr. Thomson refrains from dealing with them *as regards their ultimate transformations.*

2. – Of the three lower arches, the transformations of the lowest one are made out clearly, those of the one above, less clearly, and those of the one higher still, somewhat imperfectly.

3. – The *lowest arch,* – (the one called the *fifth* by Dr. Thomson, who counts the arches from before backwards, *i.e.,* in the order of their formation, – the one called the *first* in the Tablets, where the arches are counted from behind forwards, or from the last formed to the first formed*) disappears entirely on the right side, and forms, on the left side, both the pulmonary artery, and the *ductus arteriosus:* – The part nearest the heart forms the trunk of the pulmonary artery, which trunk becomes connected below with the anterior or pulmonary division of the primitive arterial bulb, and, higher up, gives off the right & left pulmonary arteries as two lateral branches. The more distal part forms the *ductus arteriosus.*

4. – The arch above this – (Dr. Thomson's *fourth* arch, – our *second* arch) forms, on the left side, the arch of the aorta.

5. – On the right side, following Coste & Longet, we have described this arch as disappearing entirely. Dr. Thomson, on the contrary, following Rathke, describes it as disappearing in its distal portion only, and as forming in its central portion both the innominate artery & the first part of the right subclavian.

6. – From this point, the two descriptions differ considerably: Dr. Thomson takes the German view; we have taken the French view.
They differ mainly with respect to the subclavians, vertebrals, & internal carotids: –

7. – The arch above the one just described (the *third* one both from before backwards & from behind forwards) becomes the subclavian in our description, the commencement of the internal carotid in Dr. Thomson's description.

8. – This somewhat wide divergence is accounted for by the two following facts, namely:

9. – Dr. Thomson's subclavians, – with the exception of the first part of the right subclavian, – (and also his vertebrals), are entirely new structures, *i.e.,* structures developed independently of the cervical arches.

10. – Dr. Thomson's common carotids (and also apparently his external carotids) are formed from the "anterior aortic roots," *i.e.,* from the common ascending trunks from which the arches arise in front.

11. – On the other hand, the upper part of Dr. Thomson's "posterior aortic roots," (or the trunks into which the arches open posteriorly), *i.e.,* what we have called the *primitive vertebrals,* form the terminal part of his internal carotids, while the lower part of the same roots disappear.

12. – In our description, on the contrary, the "posterior aortic roots" form *superiorly* the *permanent vertebrals,* in which the current of blood becomes reversed as soon as the 3rd arches (the subclavians) enlarge, – and *inferiorly* the *superior intercostals.*

* *I.e.,* from those *whose ultimate transformations are best known,* to those whose ultimate transformations are *least known.*

CIRCULATION of the EMBRYO PROPER—1st Tablet.

ARTERIAL SYSTEM.

Results from the metamorphoses of the primitive vertebral arteries & of the five pairs of cervical arches, and from the extension of arteries into the limbs.

The cervical arches arise from the anterior or aortic division of the bulbus arteriosus, or arterial trunk at the anterior extremity of the heart. Curving backwards on either side of the pharynx they open one behind the other into the descending portion of the first arch, all joining to form one common descending trunk, the *primitive vertebral artery*. They appear successively from before backwards, the first ones becoming modified before the following ones are formed.

The common descending trunk, or *primitive vertebral artery*, curves backwards towards the vertebral column, where it meets with its fellow. The two trunks then descend side by side along the whole length of the spine, subsequently uniting from before backwards to form the thoracic & the abdominal portions of the aorta (Seres), and also, probably, the *arteria sacra media*.

At first the five arches conveyed the blood from the heart to the primitive vertebral arteries & the aorta. And this condition remains permanent in fishes, in which the cervical arches (then termed the *branchial* arches) give off the vascular tufts to the gills.

The cervical arches, counting them *from behind forwards*, or *from the last formed to the first formed*, * are subsequently modified in mammalia as follows:

First Arch – Disappears on the right side. Forms on the left side the trunk of the pulmonary artery, & its continuation the ductus arteriosus.

Second Arch – Disappears on the right side. Expands on the left side into the arch of the aorta.

Third Arch – Develops, as the upper limbs are formed, into the subclavian arteries & the innominate trunk. The subclavians, at first small transverse branches joining the 4th arches (carotids) to the primitive vertebrals, grow in length with the upper limb, rapidly increase in size, and become the trunks from which the upper & lower portions of the primitive vertebrals are given off.

The upper portions, the current of blood in their interior having been reversed, become the *permanent vertebrals*. These latter arteries are at first separate along the whole of their course; it is only after a time that they join together within the cranium to form the *basilar*.

The lower portions lose all immediate connection with the aorta, and become the *superior intercostals*.

Fourth Arches – Their ascending portion forms the *carotids*.

Fifth Arches – Remain at the base of the brain as the *posterior communicating branches of the internal carotids* (Dalton), which branches connect these trunks to the basilar arteries formed by the junction of the upper part of the two permanent vertebrals.

* *I.e.*, from those *whose ultimate transformations are best known* to those whose ultimate transformations are *least known*. V. Appendix.

CIRCULATION of the EMBRYO PROPER — 2nd Tablet.

VENOUS SYSTEM

Is the result of the metamorphoses of the cardinal or vertebral veins and of the vitelline & umbilical veins, and also of the extension towards the heart of the veins of the lower extremities, which extension forms the inferior vena cava & the iliacs.

Cardinal or Vertebral Veins – Are four symmetrical & parallel veins, two superior & two inferior, which lie on either side and along the whole length of the spinal column, and converge towards the heart; those of either side joining to form two short trunks, the canals of Cuvier, which open into the auricular portion of the heart on either side of the vitelline or omphalo-mesenteric vein.

The cardinal veins receive numerous intercostal veins from either side of the body.

When the upper limbs are developed two of the superior intercostal veins enlarge greatly, and become the subclavians.

The portions of the superior cardinal veins situated above the subclavians then become the internal jugular veins.

The portions situated below the subclavians are developed as follows into the right innominate, superior cava, & left superior intercostal: —

The left innominate vein is at first a small communicating branch which descends obliquely from the left upper cardinal just below its junction with the subclavian, to the lower part of the right upper cardinal. This communicating branch enlarges while the part of the left upper cardinal situated below it, diminishes. The former then conveys towards the heart, first the greater part, then nearly the whole of the venous blood from the left side of the head & neck and from the left upper limb, and takes the place of the latter. – The latter, its communication with the auricle being interrupted, and the course of the blood in its interior being reversed, then becomes the superior intercostal.

The portion of the right superior cardinal vein comprised between the right subclavian & the newly formed left innominate, now becomes the right innominate.

The portion of the right superior cardinal vein situated below the left innominate becomes the superior cava.

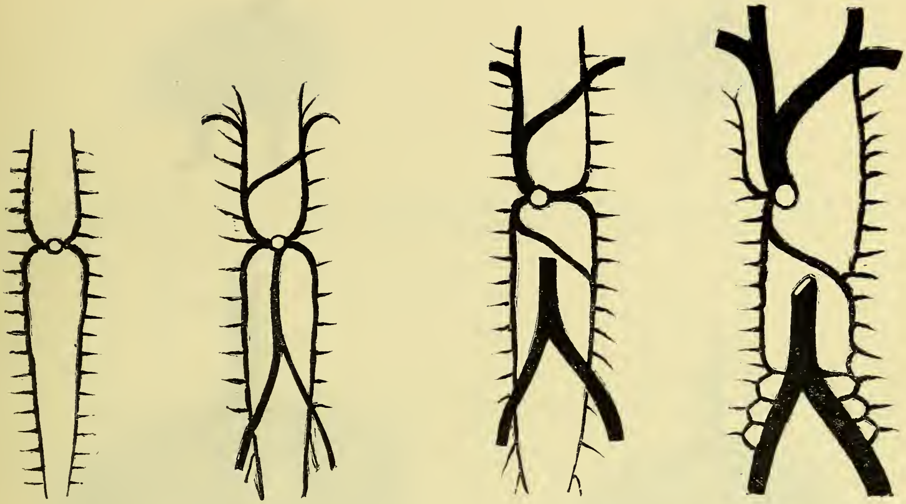
The right inferior cardinal vein forms the vena azygos major.

A communicating branch which passes from the left lower cardinal to the right lower cardinal, conveys to the latter the blood from the five or six left lower intercostals, and forms the vena azygos minor.

The left duct of Cuvier disappears, its central portion remaining however as the coronary sinus, or dilated terminal portion of the great cardiac vein, and the communication between the left lower cardinal, as well as that between the left upper cardinal & the heart becomes obliterated.

Vitelline & Umbilical Veins – Vide next Tablet.

Veins of the Lower Limbs & Inferior Cava – As the lower limbs are formed, their terminal venous trunks develop from below upwards independently of the inferior cardinal veins, and ascending between these, join with them by small branches, which become the lumbar veins. They then converge, constituting the common iliac veins, which join to form the inferior vena cava. The inferior vena cava ascends on the right side of the aorta, and opens into the auricular portion of the heart by joining with the upper part of the vitelline or omphalo-mesenteric vein.



The Cardinal Veins and their tributaries, and the Veins of the Lower Limbs (after Dalton).

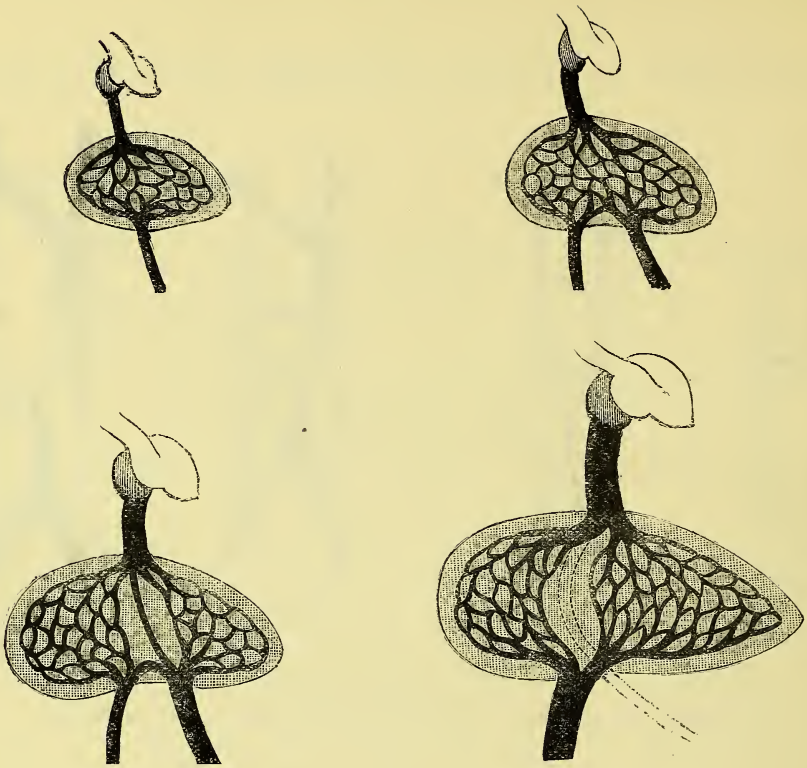
Notes on Dr. Allen Thomson's Description of the Development of the Veins.

(In QUAIN'S ANATOMY, 8th Edition, pages 796 to 798).

In this description, the term "*cardinal*" is restricted to our two *lower* cardinals. Our two *upper* cardinal veins are called the two *primitive jugulars;* and of these it is said (probably through a misprint) that, in the greater part of their extent, they develop into the *external* jugulars; it should be the *internal* jugulars, and the context shows that that is what the Author meant.

The *lowest portion* of the two cardinals, - or inferior cardinals, as we have called them, - are said to become the two *internal iliacs*.

The terms "*venæ hepaticæ adheventes,*" and "*venæ hepaticæ reheventes*" are applied to the diverging and converging branches of the left omphalo-mesenteric vein within the liver; and the right & left branches of the portal vein are said to be developed from the former veins.



The Portal Circulation (after Dalton).

The "Common Inferior Caval Trunk.

The two statements sufficiently correct in ordinary Anatomy, namely, "*that the hepatic veins open into the inferior vena cava,*" and "*that the inferior vena cava opens into the auricular portion of the heart,*" are scarcely correct in embryology; since the inferior vena cava is a vein of secondary formation. The correct statement is that both the hepatic veins (of which the left one receives the *ductus arteriosus*) & the inferior vena cava open into the *upper part of the left or persistent omphalo-mesenteric* vein, *the upper portion of which latter vein it is that opens into the auricular portion of the heart* (Vide next Tablet). – In the Tablets, the name "COMMON INFERIOR CAVAL TRUNK" has been given to *this upper part of the left or persistent omphalo-mesenteric vein, which receives the hepatic veins & the inferior vena cava;* and it is believed that the adoption of this term would lead to greater accuracy of description than generally prevails, without, however, entailing the disadvantage of a too cumbrous description.

CIRCULATION of the EMBRYO PROPER – 3rd Tablet.

VITELLINE & UMBILICAL VEINS, & FIRST PORTAL CIRCULATION.

The left or persistent vitelline or omphalo-mesenteric vein opens at first into the common auricle between the ducts of Cuvier, and then, after the separation of the two auricles, into the right auricle between the same ducts, which latter have now become transformed, the right one into the *superior vena cava*, & the left one into the *coronary sinus.*

A little below the heart, it receives the *inferior vena cava.*

A little below its junction with the inferior vena cava, it is surrounded by the liver, in the interior of which it breaks up into a capillary plexus, the branches of which plexus again unite into venous trunks, the *hepatic veins,* which latter open into what we have called the '*common inferior caval trunk*' (V. note at bottom of previous Tablet). – The portal vein is now constituted in its *first or primitive form.*

This first portal vein receives its blood *mainly at first from the umbilical vesicle:* – The umbilical vesicle is now at its maximum, while the intestine & spleen are still undeveloped: therefore the *omphalic* branches of the omphalo-mesenteric vessels, *i.e.*, the branches which proceed *from the umbilical vesicle,* must predominate over the *mesenteric* branches, *i.e.*, over those which proceed *from the intestine & spleen.* Subsequently, as, on the one hand, the intestine & spleen develop, while, on the other hand, the umbilical vesicle becomes exhausted, so also does the relative importance of the two first sources of the portal blood become reversed: – After a while the supply from the *mesenteric* branches comes to exceed the supply from the *omphalic* branches.

CIRCULATION of the EMBRYO PROPER—4th Tablet.

VITELLINE & UMBILICAL VEINS, & SECOND PORTAL CIRCULATION.

The allantoic vesicle now appears, and soon predominates in size & importance over the umbilical. It carries out with it the two umbilical arteries, and brings back the two umbilical veins, of which the right one, however, soon disappears.

The left or persistent umbilical vein joins with the left or persistent omphalo-mesenteric vein in the substance of the liver, and takes, as the allantoic vesicle increases in size while the umbilical vesicle diminishes, a more & more important share in the formation of the portal capillary plexus. – It supplies the left lobe entirely, and sends a *large communicating branch to the omphalo-mesenteric vein,* which branch partly supplies the right lobe.

There are now *two portal veins.*

CIRCULATION of the EMBRYO PROPER — 5th Tablet.

VITELLINE & UMBILICAL VS., & PERMANENT PORTAL CIRCULATION.

The liver soon receives more blood from the umbilical vein than from the vitelline, and it probably soon receives more blood than it requires. Its vessels are then relieved as follows: –

A communicating branch, the *ductus venosus,* formed by the dilatation of one of the hepatic capillaries, joins the umbilical vein to the 'common inferior caval trunk,' and conveys part of the blood from the former directly to the inferior vena cava, & to the heart.

At birth, both the *trunk of the umbilical vein* & the *ductus venosus* become obliterated, while the *branches of distribution of the umbilical vein,* & its *communicating branch* to the omphalo-mesenteric vein persist; the circulation in the latter branch being, however, *reversed.*

The portal system is then definitely constituted by: –

1. The *mesenteric branches & trunk of the left or persistent omphalo-mesenteric vein,* – the small portion of the trunk contained in the liver becoming the *right branch of bifurcation,* or the branch to the right lobe.

2. The *branches of distribution of the umbilical vein,* and the *communicating branch between this vein & the omphalo-mesenteric,* which communicating branch becomes the *left branch of bifurcation* of the portal trunk, or the branch to the left lobe.

Note - It is believed that the *separate* description of the three stages of the portal circulation will facilitate the study of this difficult subject.

THE INTESTINAL CANAL

Is nothing more at first than the upper & smaller portion of the blastodermic vesicle or yolk-sac, which upper portion is progressively enclosed in the abdominal cavity of the embryo by the bending downwards & the curving towards each other of the ventral plates, and is thus separated at the umbilicus from that lower & larger portion of the same which becomes the umbilical vesicle.

Its walls are formed from the middle & inner layers of the blastodermic membrane.* They are soon separated from the sides of the embryo, a closed serous sac, the peritoneum, being formed between the two.

The intestine is now a narrow tube closed at its cephalic & caudal ends, straight longitudinally (i.e., occupying the median line of the embryo), but curved forwards at its middle towards the umbilicus, where it communicates with the umbilical vesicle by a gradually narrowing canal, the vitelline duct. This communication persists in birds for some time after the chick is hatched.

The part above the umbilical bend forms the stomach & the greater part of the small intestine.† The part below the umbilical bend forms the large intestine & a portion of the small.

The stomach is at first straight, but it soon expands greatly to the left, and then curves transversely to the right, where an annular constriction forms the pylorus.

The duodenum again turns to the left.

Below this the small intestine proper grows greatly in length, and becomes exceedingly convoluted, the peritoneum forming the mesentry behind it.

The large intestine increases slightly in length but greatly in size, and encircles the former. — At the point of junction of the large & small intestines a conical tapering diverticulum appears, which afterwards enlarges superiorly into the caput cœcum coli, while inferiorly it elongates into the appendix vermiformis.

The stomach soon communicates with the œsophagus, which is formed independantly above it.‡

Inferiorly the rectum opens into the cloaca, or common outlet of the digestive, urinary & reproductive tracts, which itself soon opens externally. The rectum is subsequently separated from the genito-urinary organs by a transverse septum, the perinæum.

The valvulæ conniventes of the small intestine & the pouches of the large appear a little after the middle of fœtal life. Villi then exist throughout the intestine, but they subsequently disappear below the ileo-cœcal valve.

Notes.

* *I.e.*, from the splanchnopleure & the hypoblast.

† And also, according to the more modern view, the pharynx & the œsophagus.

‡ This is the older view. According to the more modern view, the pharynx & the œsophagus are derived from the same source, and are formed at the same time, as the abdominal or intestinal portion of the alimentary canal; and it is the *pharynx* which comes to communicate with the mouth *at the fauces.* (See page 134)

ITS APPENDAGES.—AIR PASSAGES.

The *tubular glands* of the stomach & intestine, and the *liver* & *pancreas*, are developed as depressions, ramified depressions in the case of the two latter, of the portions of the middle & inner germinal layers which form the intestinal walls.– The *liver* is at first a bifid depression of the portion of the intestinal wall situated just below the stomach. It grows very rapidly, especially at first, and weighs during the first month 12 per cent. of the weight of the body; its relative weight falls subsequently however to 10, 8, and at birth, to 3 or 4 per cent. It secretes but a relatively small amount of bile, or more correctly, perhaps, of the colouring matter only, for the biliary acids are said to be wanting. – The *pancreas* is developed in a similar manner – The *spleen* is probably formed independently of the intestinal canal, and from a separate mesoblastic mass.

The *lungs* commence as two outgrowths from the front of the pharynx, which outgrowths rapidly divide & subdivide into very numerous processes. At first they are solid, but they are subsequently hollowed out into the bronchi, bronchial tubes, & air cells. The bronchi open into the pharynx at first separately, but subsequently by a common trachea & larynx,– these latter organs being formed by a depression of the portion of the pharyngeal wall upon which the bronchi first opened.

The *diaphragm* is formed after the lungs as a gradually widening annular protrusion of the thoraco-abdominal walls, which annular protrusion closes slowly in the centre, and separates the pericardium & pleuræ from the peritoneum, and the thorax from the abdomen.

THE URINARY ORGANS — 1st Tablet.

THE WOLFFIAN BODIES.

The Wolffian bodies, or primordial kidneys, appear very early in the intermediate cell mass (V. page 125) as two fusiform structures situated on either side of the primordial vertebræ. They develop simultaneously with the intestine & liver, and are completely formed by the end of the sixth week.

They then extend from just below the heart to near the posterior extremity of the embryo, and weigh nearly 3 per cent. of the weight of the whole body.

Their duct descends from their outer aspect to the uro-genital sinus, and conveys into that sinus & into the urinary bladder, a fluid very similar to urine.

This duct is the part first formed. It appears as a solid cord in the upper part of the intermediate cell mass just below the epiblast, sinks downwards towards the pleuro-peritoneal cavity, and becomes hollow.

The secreting tubules spring from its inner side. These tubules take a wavy course inwards, or upwards and inwards, and end in dilated extremities, which soon contain vascular tufts or glomeruli very similar to those of the kidney.

When the kidneys appear, the Wolffian bodies cease to grow, and become atrophied. They are scarcely seen in the human embryo after the end of the third month. — Their remnants, the organ of Giraldes & vas aberrans in the male, the organ of Rosenmüller *(epoophoron & paroophoron)* in the female, subsequently accompany the testicle or ovary in its descent.

Note — In correspondence with the more modern view of the homologies of the genital ducts (V. page 160), the Wolffian body has been described as presenting an upper, non-glomerular, or so-called genital portion devoid of tufts. The tubules of this upper portion have been said to develop into the *coni vasculosi*, and thus to establish the communication between the tubuli seminiferi of the testicle & the Wolffian duct necessary for the transformation of the latter into the *epididymis, & vas deferens.* — It has however been shown by Cleland & by Banks that the coni vasculosi & the tube that unites them are developed as new structures.

THE URINARY ORGANS—2nd Tablet.

THE KIDNEY.

Is formed in the intermediate cell mass, or common reproductive cell mass, below & behind, and a little later than, the Wolffian body.

Its first rudiment is a diverticulum from the upper & back part of the Wolffian duct. This diverticulum becomes the ureter.

Smaller diverticula radiate from the ureter into the common reproductive cell mass, and form the tubuli uriniferi, whose dilated extremities soon contain the Malpighian tufts or glomeruli.

These tubuli are at first wide, short, & straight. As they lengthen, they become narrow & flexuous, and constitute the *cortical substance*. Their central ends remain straight, however, and group themselves into *pyramids* about fifteen in number, thus forming the medullary substance.

The kidney is at first large, globular in form, & more or less lobulated.

THE URINARY ORGANS — 3rd Tablet.

THE URINARY BLADDER.

Is formed from the intra-fœtal portion of the allantois.

It is at first an elongated fusiform sac opening, on the one hand, into the cavity of the allantois, and, on the other, into the cloaca, or common outlet of the digestive, urinary & reproductive tracts.

It contracts superiorly into a fibrous cord, the urachus, by which it remains permanently connected to the umbilicus.

Inferiorly it becomes separated from the intestinal canal by a transverse septum, the perinæum.

It then forms part of the uro-genital sinus, which sinus forms the female urethra, and the membranous & prostatic portions of the male.

THE GENITAL ORGANS—1st Tablet.

THE CENTRAL GENITAL GLAND (Testicle or Ovary).

Presents at first precisely the same appearance, to whichever sex the fœtus is subsequently to belong.

It is formed from the intermediate cell mass & the peritoneum covering it, and about the same time as the kidney, but in front & to the inner side of the Wolffian body.

The peritoneum covering the intermediate cell mass becomes thickened in two situations, namely, along its inner side, where this thickening gives rise to an opaque white ridge, the *germinal ridge*, and along its outer side, where, by a process of involution, the Müllerian duct is formed.

In the case of the female, the ova result from the enlargement of the cells of the germinal ridge (V. next Tablet but one). They soon become embedded in the surrounding mass, which develops into the stroma of the ovary.

In the case of the male, the cells of the germinal ridge soon become atrophied, and the glandular substance develops in the intermediate cell mass independently of them (V. next Tablet).

THE GENITAL ORGANS — 2nd Tablet.

SUBSEQUENT EVOLUTION of the TESTICLE.—SPERMATOZOA.

The tubuli seminiferi are at first solid rows of cells.

They hollow out into tubes, lengthen, become convoluted, diminish in diameter, and branch.

A condensed fibrous covering forms the *tunica albuginea,* and sends processes inwards, which processes separate the lobules.

The spermatozoa are developed from the modified epithelial cells of the tubuli seminiferi, which Neumann has described of late under the name of *spermatoblasts.*

The *spermatoblasts* are pyramidal protoplasmic columns, whose bases rest upon the fibrous wall of the tubuli, while their apices converge towards the lumen.

They present a large nucleus near their centre, and, towards their bases, from ten to twelve nucleoli.

The nucleoli become the bodies of the spermatozoa. The central protoplasmic substance of the spermatoblasts splits up to form the commencement of the tails (the part sometimes called the *collar*).

This evolution, commenced *in situ,* is completed during the progress of the detached spermatoblasts through the rete testis & the vasa efferentia.

The tails lengthen, coil up, and burst through the cell wall; the spermatozoa are thus set free.

THE GENITAL ORGANS — 3rd Tablet.

SUBSEQUENT EVOLUTION of the OVARY. — OVA, GRAAFIAN FOLLICLES.

When embedded in the ovary, the cells of the germinal ridge become transformed into ova as follows: – Their protoplasm becomes the *yolk;* their nucleus becomes the *germinal vesicle;* their nucleolus becomes the *macula* or germinal spot. The *vitelline membrane* or *zona pellucida,* results from the subsequent consolidation of the outer stratum of the yolk (Foulis).

The outer wall of the Graafian follicle results from the condensation of the ovarian stroma, processes of which stroma surround the epithelial cells first collectively, then singly (Waldeyer, Foulis).

The origin of the inner layer or *membrana granulosa* is still a disputed point: – According to Waldeyer it is formed from cells of the germinal ridge, smaller & less developed than those which become ova; which smaller & less developed cells would be enclosed between the processes of the stroma along with the larger ones. According to Foulis it is formed, along with the outer wall, from the cells and nuclei of the stroma itself.

The follicular walls thicken and become vascular; and the granular cells multiply in their interior.

Finally a space is formed in the centre of the follicle, in which space fluid accumulates; and the ovum, surrounded by a mass of cells, the *discus proligerus,* is pressed towards the peripheral wall of the follicle.

Such a number of ova and follicles are formed in this way, that, about the fifth or sixth month of fœtal life, the ovary appears to consist of nothing else.

A month or two later, some of the follicles enlarge considerably, and sink in towards the ovary; – the enlarging follicles of later years rise up, on the contrary, from the deeper parts towards the surface.

THE GENITAL DUCTS.

THE OLDER VIEW :-

As the genital glands & the external genitals are homologous in the male & female, so are also the genital ducts ; -

Muller's Ducts - Form :

Fallopian Tubes, Uterus, & Vagina, in the female,

Epididymes, Vasa Deferentia, & Ejaculatory Ducts, in the male.

Wolffian Bodies & Ducts - Dwindle down, on the contrary, into ;

Organs of Giraldes, & vasa aberrantia in the male,

Parovaria, or Organs of Rosenmuller, & Gaertner's Canals, in the female.

Remarks - We are here face to face with two conflicting views; and such is the importance & interest of the matter in dispute, that it has been thought desirable to give an outline both of the conflicting views in question, and of the facts & arguments upon which they are respectively based.

The view described as the *More Modern* is, with a few slight modifications, the one advocated by the old German physiologists Rathke, Bidder, Weber, Kobelt, Meckel & others, in opposition to the view of J. Müller (1832, 1846 to 1848). It was opposed by the physiologists of the French School, Coste, Longet, Follin, and is still opposed by Robin; nor was it generally received by English physiologists for many years after it had been put forth : - Dr. Cleland opposed it in 1856 ("Structure & Mechanism of the Gubernaculum Testis") ; Mr. John Marshall, F.R.S., writing as late as 1867 ("Physiology, Human & Comparative"), ignores it entirely.

On the other hand, Dr. Carpenter noticed it somewhat favourably in his "Principles of Human Physiology" (4th Edition, 1853), and supported it in the 5th Edition (1855) in a foot-note which runs as follows, and which has been preserved in all the subsequent Editions revised by Mr. H. Power : -

"Although it has usually been considered that the vasa deferentia of the male and the Fallopian tubes of the female "are homologous organs, yet this does not seem to be really the case." . . . (See Kobelt "Der Nebeneierstock des "Weibes." Heidelberg, 1847.)

In the later editions, further quotations have been introduced from Mr W. M. Banks' prize essay in support of the more modern view.

Dr. Sharpey, writing in the 5th & 6th Editions of Quain's Anatomy, holds an even balance between the two views : -

"The mode of origin of the Fallopian tubes & vasa deferentia has been differently explained by different enquirers. "In the mammalia, the Fallopian tube, as well as the vasa deferentia, is supposed by J. Muller to be formed out of a dis- "tinct canal along the outer border of the Wolffian Body. Rathke first maintained that both the Fallopian tube & the "vas deferens are formed independently of the Wolffian duct ; but he has since been led to adopt a somewhat different "opinion founded on his researches on the development of the snake (but which he thinks will probably apply also to the "other vertebrata). In the female, according to this view, the duct of the Wolffian body, as well as the body itself, is "entirely absorbed, whilst the new canal constitutes the Fallopian tube ; but, in the male, the reverse takes place, the "newly formed canal disappearing, and the Wolffian duct becoming the vas deferens ; whilst some of the tubuli of the "Wolffian body, remaining in connexion with the duct, usually contribute to form the epididymis. Bischoff, after a "careful examination of these parts, declares that the filament formed along the outer border of each Wolffian body "contains, not only the excretory duct of that gland, but also an efferent sexual duct, which is the rudiment of the "Fallopian tube, or of the vas deferens, and that both these are formed independently of the Wolffian body." *(Slightly altered for the sake of condensation).*

— DISPUTED HOMOLOGIES.

THE MORE MODERN VIEW :-

Though the genital glands & the external genitals are homologous, or nearly so, in the male & female, the genital ducts are not homologous. The male ducts correspond on the contrary to relatively unimportant structures in the female; and the female ducts correspond likewise to relatively unimportant structures in the male : –

Muller's Ducts – Form :

FALLOPIAN TUBES, UTERUS, & VAGINA, in the female, while, in the male, they dwindle down into the

Vesicula Prostatica, Sinus Pocularis, or Organ of Weber, which is the homologue of the uterus & vagina of the female, and into the

Hydatids of Morgagni.

Wolffian Bodies & Ducts – Form :

EPIDIDYMES (body & tail), VASA DEFERENTIA, & EJACULATORY DUCTS, and also the *Organs of Giraldès & Vasa aberrantia of Haller,* in the male, while, in the female, they dwindle down into the

Organs of Rosenmuller (Epoophoron & Paroophoron), & Gaertner's Canals.

Dr. Allen Thomson & Dr. Cleland, writing conjointly in the 7th Edition of Quain's Anatomy (1857), and Dr. Allen Thomson writing in the 8th Edition of the same work (1876), appear to be the first English authors who mention no other view than the *More Modern* one. The latter writer quotes extensively from Messrs. Foster & Balfour, as all other authors have done since the appearance of their "Elements of Embryology" (1874).

If we now turn to the critical examination of the two views, we shall immediately see that they agree with respect to the female organs: Both admit that the Fallopian tubes, uterus, and vagina are formed from the Müllerian ducts, and that, *in the female,* the Wolffian ducts dwindle down into unimportant residual structures. It is with regard to the male organs only that the two views differ.

They differ in this way : – In the older view it is asserted that the vasa deferentia are the homologues of the Fallopian tubes, and that they are developed, as are the latter, from the Müllerian ducts. In the more modern view it is asserted that the vasa deferentia are not the homologues of the Fallopian tubes, and that they are not developed from the Müllerian ducts, but are developed, on the contrary, from the ducts of the Wolffian bodies, or Wolffian ducts. In the male, therefore, according to the more modern view, the Wolffian ducts would at first be connected with the Wolffian bodies and would serve for the excretion of the fluid formed by the latter, namely, modified urine. They would then cease to be connected with the Wolffian bodies and to excrete urine, and would become connected to the testicle and serve for the excretion of the sperm.

With these two first conflicting statements, namely : –

It is Muller's ducts that form the vasa deferentia (THE OLDER VIEW) ;
It is the Wolffian ducts that form the vasa deferentia (THE MORE MODERN VIEW) ;

are therefore correlated the following equally conflicting statements, namely : –

The Wolffian ducts dwindle down into residual structures in the male as well as in the female (THE OLDER VIEW) ;
It is only in the female that the Wolffian ducts dwindle down into residual structures ; in the male, it is Muller's ducts that so dwindle down. The Wolffian ducts rise, on the contrary, to the pre-eminent office of excretory ducts of the testicle (THE MORE MODERN VIEW).

P.

THE GENITAL DUCTS.—2nd Tablet.

THE TWO VIEWS DISCUSSED:- Direct Observations; Collateral Evidence.

In this matter, direct observations appear somewhat inconclusive. A perusal of the criticisms of their opponent's views by those who hold the older view will, it is believed, confirm this impression:- Says Longet: "Rathke prétendit que les Corps de Wolff disparaissent totalement chez les femelles, mais qu'ils persistent en partie chez les mâles "pour former l'épididyme. J. Müller pensa que leurs conduits excréteurs *se transforment en canal déférent.* Coste *redressa cette erreur*...... On peut y distinguer trois "parties, une externe, sorte de filament ou de canal. Le filament externe est composé "de deux canaux placés à coté l'un de l'autre: le plus externe deviendra *l'épididyme et "le canal déférent chez le male, l'oviducte chez la femelle;* l'interne, au contraire, appar-"tient bien réellement au corps de Wolff, dont il constitue le canal excréteur. *Le "parallelisme du spermiducte ou de l'oviducte avec le canal excréteur au corps de Wolff a été "la cause de l'erreur.* Les corps de Wolff sont complétement indépendants de toutes "les productions environnantes; ils sont *également étrangers, et aux organes urinaires et "aux organes génitaux internes*...... Plus tard, le corps de Wolff se complique. Les "tubes creux et aveugles qui contribuent à le former s'accroissent d'une manière plus "ou moins considérable, et l'espace dans lequel se fait leur développement ne grandissant pas proportionnellement à la quantité dont ils s'allongent, ils se replient sur "eux-memes, se contournent, et prennent *l'aspect d'un épididyme.* L'épididyme "commence à se former par un enroulement de l'extremité du spermiducte, ce qui a "pu contribuer à faire adopter *l'opinion erronée qu'il provenait du corps de Wolff* "(LONGET, Traité de Physiologie; Second volume, pages 852 à 854).

Collateral Evidence is adduced *in support of the older view, firstly,* from the respective homologies (complete, or nearly so) of all the other parts of the genito-urinary system in the male & female; *secondly,* from what may be considered as the *apparent prima facie* improbability, that, in the male, one & the same duct (the Wolffian duct) should serve as the excretory canal first for one gland (the Wolffian body) and then for another (the testicle), and that, on the other hand, a duct should be formed (the Müllerian duct) seemingly an excretory duct, which is to serve no excretory purpose whatever; and, *thirdly,* from the asserted absence of examples of double vertical hermaphrodism.

Collateral evidence is adduced *in support of the more modern view* from considerations in respect of the vesicula prostatica & of Gaertner's canals, and from alleged examples of double vertical hermaphrodism.

The view of the homology of the vesicula prostatica or sinus pocularis with the uterus (Weber), or rather with the uterus & the vagina (Leuckhart), necessarily leads to the view that the diminutive cornua, which this sinus presents in many mammals, are derived, like the cornua of uterus, from the Müllerian ducts; and from the fact that these cornua are not prolonged into anything, which can be compared with the Fallopian tubes of the female, it is further concluded that the Müllerian ducts must disappear in the male, except as regards their most central portions.

Further, in the hypothesis of the homology of the vesicula prostatica with the uterus & vagina, the opening of the ejaculatory ducts just within the margin of the vesicula is highly suggestive of the homology of these ducts, and of their prolongations, the vasa deferentia, with the canals of Gaertner, which, in the early condition of the female of the pig, calf, lamb, & some other mammals, open into the vagina on either side, close to the vulva. These ducts of Gaertner are the remnants of the Wolffian ducts. Therefore it must be these same Wolffian ducts, *i.e.,* these ducts which disappear or at least dwindle down into unimportant residual structures in the female, that become, in the male, the vasa deferentia.

The term *double vertical hermaphrodism* is descriptive of such abnornal cases as may present, *on the same side,* both a testicle & an ovary. If such cases really do exist, as there are but two fœtal ducts in connexion with the central genital organs, one of these ducts must become the excretory duct of the ovary, and the other the excretory duct of the testicle. These ducts, therefore, are not the homologues one of the other. Hence, as, in the female, the evolution of the ovary & non-evolution of the testicle entail as a consequence the persistence of the Müllerian duct & the atrophy of the Wolffian duct; so also, in the male, does the evolution of the testicle & non-evolution of the ovary entail the persistence of the Wolffian duct & the atrophy of the Müllerian duct.

THE GENITAL DUCTS.—3rd Tablet.

THE VIEWS of WEBER, as supported by CARPENTER & POWER.

The uterus & vagina are not formed by the coalescence of the lower part of Müller's ducts. They are developed from a portion, – the genital portion, – of the uro-genital sinus, which sinus is evolved on exactly the same plan in both sexes, as will presently appear.

The uro-genital sinus is a part of the primitive allantois. It therefore communicates superiorly with the urinary bladder. Into it open posteriorly both the Wolffian ducts & Müller's ducts (the common bundle formed by these ducts being sometimes called the *genital cord*).

As soon as the perinæal septum is formed, the uro-genital sinus is found to open externally in front of the anus, in the situation of the future vulva of the female (V. External Genito-Urinary Organs.) This condition is common to both sexes.

One further modification, now to be described, also occurs in both sexes, and it is only after the occurrence of this modification that sexual divergences begin. The modification in question is the *division*, by means of a transverse septum, *of all but the lowest part of the uro-genital sinus into an anterior, or urinary portion, & a posterior, or genital portion.*

The *anterior or urinary portion* becomes *the urethra proper, i.e.*, the urethra of the female, or the prostato-membranous portion of the urethra of the male. (The spongy portion of the urethra of the male is a subsequent structure formed as described below.)

The *posterior or genital portion* becomes the *vagina & uterus* in the female, *or* the *vesicula prostatica* in the male. This is effected as follows: the male organs simply make no advance in volume or complexity; the female organs, on the contrary, increase in size, and a constriction divides them into two parts, of which the upper one, the uterus, thickens from below upwards.

The lower and undivided portion, or aperture, of the uro-genital sinus forms the *atrium vaginæ* in the female, *i.e.*, the combined fossa navicularis & vestibule, which parts are bounded by the now formed labia minora & clitoris.

In the male, the uro-genital sinus is continued into the *spongy, or superadded, portion of the urethra,* which latter is formed by the mesial union of the homologues of the labia minora (V. External Genito-Urinary Organs).

REMARKS – In this view, we have, opening into the female atrium, both the urethra & the vagina, and, through the vagina & its continuation, the uterus, both Müller's ducts (Fallopian tubes) and the Wolffian ducts (Gaertner's canals); and so also we have, in the male, both the urethra (the urethra proper) and the vesicula prostatica, and through the vesicula prostatica, both Müller's ducts & the Wolffian ducts, opening into what corresponds to the female atrium.

This view weakens slightly, as far as it is based upon homologies, but only very slightly, the view that the vasa deferentia are differentiated Wolffian ducts. (V. appendix page 163 A.)

THE GENITAL DUCTS.—4th Tablet.

THE GENITAL CORD or COMMON GENITAL BUNDLE.—(Classical View).

The genital cord is the common bundle formed by the approximation of the Wolffian & Müllerian ducts of either side a little above their point of entrance into the uro-genital sinus; – which bundle becomes greatly thickened by deposition of tissue between & around the ducts.

The Müllerian ducts lie between & behind the Wolffian ducts, and they unite into one canal before they open into the uro-genital sinus.

In the female subject, the common canal thus formed becomes the *vagina*, the *cervix*, & the *greater part of the body* of the uterus.

The portions of the Müllerian ducts above this become the *cornua* of the uterus, which latter remain comparatively short in the human female.

The remainder of the Müllerian ducts become the *Fallopian tubes.*

The thickening of the walls of the uterus begins at the *os*, and progresses from below upwards: For some time after birth, the cervix is larger & thicker than the body.

Incomplete union of the Müllerian ducts gives rise to the *uterus bicornis* or *horned uterus* common to many mammals; their imperfect union may give rise to a double uterus, and even, occasionally, to simultaneous duplicity of the vagina.

The Müllerian ducts being formed by an involution of the peritoneum, the female passages & their mucous membrane are continuous with the pleuro-peritoneal cavity & its epithelium.

In the male, the united portions of the Müllerian ducts become the *sinus pocularis* or *vesicula prostatica.*

The Wolffian ducts open into the uro-genital sinus on either side of, and below the Müllerian ducts.

In the female they dwindle down to the condition of a residuary duct (Gaertner's canal), which joins the outer extremities of the tubules of the parovarium or organ of Rosenmüller.

In the male, they become the *canal of the body & tail of the epididymis*, the *vasa deferentia*, and the *ejaculatory ducts*; diverticula from their walls form the *vesiculæ seminales.*

The *prostate gland* results from the thickening of the whole of the lower part of the genital cord.

THE RESIDUAL GENITO-URINARY ORGANS.

OF THE FEMALE:-

Parovarium, Organ of Rosenmuller, or Epoophoron, & Gaertner's Canals.— Paroophoron.

The *Parovarium, or Organ of Rosenmuller,* is due to the persistence of the upper, non-glomerular, or so-called sexual portion of the Wolffian body; it closely corresponds, therefore, to the epididymis of the male. It is scarcely correct, however, to consider it as the homologue of the epididymis, since it has been shown by Cleland and by Banks that the coni vasculosi & the tube that unites them are developed as new structures.

It consists of a group of scattered tubules lined with epithelium, which lie more or less transversely in the broad ligament of the uterus between the Fallopian tube & the ovary. These tubules are closed at their inner ends, which converge towards each other; but they open at their outer ends into a vertical canal, which is the remnant of the Wolffian duct. This canal passes downwards in the direction of the vulva, and usually becomes lost; but in the early condition of the female of the pig, calf, lamb, & some other mammals, it is seen to open into the vagina close to the vulva. It is then known as Gaertner's canal.

The vestige of the lower, glomerular, or primordial-kidney portion of the Wolffian body may sometimes be detected, occasionally even in the adult female, on the inner side of the foregoing organ, between it & the uterus. It consists of small cysts, or obscure & imperfect tubular remains. Waldeyer calls it the *paroophoron,* to distinguish it from the foregoing, which he calls the *epoophoron.*

The Fallopian tube sometimes presents one or two small additional fimbrated openings at a short distance from its extremity. These are probably due to the imperfect closure of the Müllerian duct.

OF THE MALE:-

Organ of Giraldes, or Paradidymis; Vas Aberrans; Hydatid of Morgagni.—

The *Organ of Giraldes* is the remnant, in the male, of the lower, glomerular, or primordial-kidney portion of the Wolffian body. By Waldeyer, it is called the *paradidymis,* in correspondence with its homologue, the *paroophoron* of the female. It lies in the lower & front part of the spermatic cord close to the head of the epididymis, and consists of a collection of minute convoluted tubules lined with epithelium.

The *Vas Aberrans of Haller* is probably also a remnant of some part of the Wolffian body, but its precise origin has not yet been clearly made out. It is a narrow tortuous tube from 1½ to 14 inches long, connected with the commencement of the vas deferens or with the lower part of the canal of the epididymis, passing upwards for an inch or more among the other elements of the spermatic cord, and ending in a blind extremity. It is sometimes quite unconnected with the permanent seminal ducts. It is sometimes branched, and occasionally there are two or three tubes instead of one.

The *Hydatid of Morgagni* is probably a remnant of Müller's duct. It is a small pedunculated mass of connective tissue & blood-vessels surrounded by a fold of the tunica vaginalis, and situated on the upper extremity of the testicle, just in front of the globus major of the epididymis; sometimes there are several hydatids instead of one. – A similar body is frequently found in connexion with the free end of the Fallopian tube.

THE EXTERNAL GENITO-URINARY ORGANS.—1st T.

Appear a little after the internal, and are also identical at first in both sexes.

A rounded eminence arises below & behind the symphysis pubis, and on it appears a median depression or slit.

This slit grows deeper & deeper, and soon opens into the cloaca, or common outlet of the intestinal canal and of the internal genito-urinary organs.

A transverse septum, the perinæum, now separates the rectum from the uro-genital sinus, and the anus from the external genitals.

The uro-genital sinus is the lowest & contracted part of the intra-fœtal portion of the allantois. It communicates superiorly with the urinary bladder. Into it open, first the Wolffian ducts, and then the ureters & the Müllerian ducts. It subsequently contracts to form the female urethra, and the prostatic & membranous portions of the male urethra.

The growth of the uterus & vagina separates, in the female, the genital canal from the urinary.

Sexual differentiations now appear externally:—

Two elongated & obliquely disposed eminences are formed on either side & in front of the uro-genital opening. They converge anteriorly to form, in the male, the corpora spongiosum & cavernosa, in the female, the clitoris & the labia minora; a slit or groove remaining for a time on the under surface of the former.

In the male, the corpora cavernosa & spongiosum extend upwards. The lower margins of the latter soon join, closing the median groove inferiorly, and forming the spongy portion of the urethra. In the female, the clitoris tends to bend downwards.

Two cutaneous appendages appear on either side. In the female, they remain separate as the labia majora. In the male, they join from behind forwards to form the scrotum, into which the testicle descends at birth.

THE EXTERNAL GENITO-URINARY ORGANS.—2nd T.

ADDITIONAL NOTES.

The mode of formation of the perinæal septum has not yet been made out very clearly. It would appear that the deeper parts are formed first, by the union of two transverse bands which project on either side from the lateral & back part of the cloaca; and that it is only subsequently that those superficial structures arise which form the perinæum proper.

The groove on the under surface of the future erectile organ is frequently called the *uro-genital groove* on account of its being the continuation, so to speak, of the uro-genital sinus. In the female, the margins of this groove widen out into the *labia minora* or *nymphæ*. In the male, they unite from behind forwards to form the spongy portion of the urethra, which portion is therefore the homologue of the atrium vaginæ.

The *glands of Bortholin*, which open into the female atrium, are the homologues of Cowper's glands, which open, in the male, into the back part of the spongy portion of the urethra, or into what is sometimes called the *bulbous portion*.

The *bulbi vestibuli* of the female are the homologues of the two lateral halves of the urethral bulb of the male; and the *partes intermediæ* of Kobelt are probably the homologues of the two lateral halves of the remainder of the corpus spongiosum urethræ.

In the female, these parts remain separate, except quite anteriorly where they join to form the glans clitoridis.

In the male, the two halves of the corpus spongiosum unite from behind forwards both above & below the urethra, forming its erectile coat, and then swell out anteriorly to constitute the glans penis: the grooves on the under surface of the bulb & glans are traces of the primitive bifid condition of these parts. Imperfect union either above or below may give rise to epispadias or hypospadias respectively.

The *hymen* & *prepuce* are formed as projecting folds of the mucous membrane of the atrium vaginæ, & of the integument of the penis respectively.

THE DESCENT of the TESTICLE.

Up to the

5th Month – The testicle lies in the *lumbar region in front of & a little below the kidney;* it is *enveloped* by the *peritoneum,* which forms behind it a suspensory fold or mesentery, the *mesorchium,* in which fold are contained the vessels & nerves of the testicle.

The descent of the testicle is effected as follows, according to Curling: –

To the *tail of the epididymis* is *attached* the *upper enlarged extremity* of a conical muscular cord, the *gubernaculum testis,* which cord passes down upon the psoas beneath the peritoneum, and descends through the inguinal canal into the bottom of the scrotum, where it ends in a pointed extremity attached to the dartos.

This gubernaculum testis is formed by the cremaster muscle. The cremaster, before its inversion in the course of the descent of the testicle, is a *tube of striped muscular fibres* attached superiorly to the tail of the epididymis, and *divided inferiorly* into *three processes,* which processes are *attached* respectively, the external & broadest one to *Poupart's ligament* in the inguinal canal, the middle & longest one to the *dartos* at the bottom of the scrotum, and the inner one to the *front of the pubes* & to the *sheath of the rectus* muscle; this tube surrounds a process of cellular tissue, which process appears sometimes to be partially hollow.

The *conjoined action of the three* muscular *fasciculi* of the gubernaculum draws the testicle

Between the 5th & 6th Months – Into the *iliac fossa,* and

By the 7th Month – Into the *inguinal canal.* – The conjoined action of the *internal & middle fasciculi* draws the testicle

During the 7th & 8th Months – *Through the inguinal canal.* – Lastly the *middle fasciculus* draws the testicle

By end of 8th Month – Into the *bottom of the scrotum.*

During the descent of the testicle

Its *proper peritoneal covering* becomes elongated, and forms the *tunica vaginalis propria;*

The *parietal layer of peritoneum* over the internal abdominal ring is depressed into the scrotum, and forms the *tunica vaginalis reflexa;*

The *fascia transversalis* is similarly depressed, and forms the *infundibuliform fascia* & the *fascia propria;*

The *muscular fibres of the gubernaculum* are *everted,* and become external to the process of peritoneum & to the fascia transversalis, and form the *cremasteric fascia.*

Cleland, Dalton, & others maintain, however, that the *gubernaculum* testis, whatever be its nature & functions in some of the lower animals, is *not* in man a *muscular organ;* that it takes *no active part,* at least in man, *in the descent of the testicle,* which descent is, they say, occasioned by the process of growth taking place in different directions at successive periods of fœtal life; also that the process of *peritoneum* which subsequently forms the tunica vaginalis reflexa, far from being depressed by the testicle during its descent *passes down* on the contrary, *in advance of the testicle,* which latter organ then enters into a preformed pouch patent & ready to receive it.

THE DESCENT of the OVARY.

The ovary lies at first in the female embryo in the same position as does the testicle in the male, and is similarly enveloped by peritoneum and similarly connected to the gubernaculum. This latter crosses the Müllerian duct posteriorly, and then courses, as in the male, through the inguinal canal, and is lost in the subcutaneous tissue in front of the pubes.

It is that portion of Müller's duct which lies internally to the gubernaculum, that enters into the formation of the uterus, and that portion which lies externally to the gubernaculum, that forms the Fallopian tube.

The gubernaculum itself, becoming adherent to the point of junction of these two portions of the internal genitals, forms, in its upper part, the ligament of the ovary, and in its lower part, the round ligament of the uterus.

As the ovaries descend, they pass below & behind the Fallopian tubes, which necessarily perform at the same time a movement of rotation from above downwards & from before backwards.

The round ligament, the Fallopian tube, and the ovary & its ligament, become enveloped in double folds of the peritoneum, which enlarge with the growth of these organs and constitute the broad ligaments of the uterus.

THE PLEURO-PERITONEAL CAVITY.

Is the intra-fœtal portion of the space formed on either side of the common reproductive cell mass by the splitting of the mesoblast into splanchnopleure & somatopleure; – the extra-fœtal portion of this space being the space comprised between the amnion proper & the false amnion, into which space the allantois spreads out to form the endochorion.

This space is divided from the first into two lateral halves by a mesial septum formed of two peritoneal layers.

Each lateral half is then divided by the formation of the diaphragm into an *upper, thoracic, or pleural portion*, and a *lower, abdominal, or peritoneal portion.*

The two halves of the *thoracic or pleural portion* remain distinct, the mediastina & the heart being included between them. * – The pleura covers at first but the outer surface of the lung; it invests the organ more completely as soon as the latter becomes detached from the œsophagus.

In the *lower or abdominal portion*, the two cavities become fused into one in front of the intestine.

The mesial septum persists, however, behind the intestine.

Behind that central portion of the intestine which curves forwards towards the umbilicus, joins with the umbilical vesicle, and forms the small intestine, it forms the *mesentery proper.*

Behind the portion above this, *i.e.*, behind what becomes the transverse colon, it similarly forms the *transverse meso-colon.*

A little higher up, *i.e.*, behind what becomes the stomach, it forms the *meso-gastrium*, which latter fold becomes, on the one hand, the *lesser or gastro-hepatic omentum*, and comes to form part, on the other hand, of the *greater or gastro-colic omentum.*

Higher up still, it invests the liver, and forms its *suspensory & coronary ligaments.*

* The serous layer of the pericardium may be considered as the central portion of the two pleuræ cut of from the remainder by the formation of the fibrous bag, and fused into one cavity.

TRANSFORMATIONS of the MESO-GASTRIUM.—GREATER & LESSER OMENTA.—SAC of the OMENTUM.

The stomach first occupies a mesial position. The meso-gastrium is then a mesial fold, the anterior border of which is free. Superiorly, this anterior border passes up to the liver to form the *lesser or gastro-hepatic omentum.* Inferiorly, it becomes lost on the posterior wall of the abdomen a little above the transverse meso-colon.

As the stomach turns over to the right, so does also the lesser or gastro-hepatic omentum: – This fold comes to form part of the *anterior wall of the omental sac;* and its free border comes to form the *anterior boundary of the foramen of Winslow.*

As the stomach elongates & expands, so does also the lower part of the meso-gastric fold: – This fold comes to form the *great omentum*, into which the omental sac is prolonged.

A distinction must here be made between the *great omentum of the fœtus & young child*, and the *great or gastro-colic omentum of the adult: – In the early condition*, the two posterior or ascending layers of the great omentum pass up in front of the transverse colon without adhering to it, and then pass backwards to the spine above the transverse meso-colon, with which they are in no wise connected. At the spine, the two layers separate: – The superior one passes up to the liver. The inferior one passes forwards to the transverse colon, forming the upper layer of the transverse meso-colon; surrounds the transverse colon; passes back to the spine, forming the under layer of the transverse meso-colon; and then descends to form the mesentery proper. There exists therefore a depression or pouch between the most posterior of the four layers of the great omentum & the upper layer of the transverse meso-colon. *In the more advanced condition*, this pouch disappears little by little by the adhesion of its walls one to the other. This leads to the fusion of the two ascending layers of the great omentum, the one with the upper layer, the other with the under layer of the transverse meso-colon, respectively. The great omentum of the fœtus then becomes the gastro-*colic* omentum of the adult.

DEVELOPMENT OF THE BONES.

I.

SKELETAL MATRIX AND DEVELOPMENT OF BONE TISSUE.

(Pages 172 to 179.)

II.

OSSIFICATION OF THE INDIVIDUAL BONES.

(Pages 180 to 192.)

THE SKELETON.

The skeleton is developed from the middle germinal layer, or mesoblast.

Its ossification is preceded (except in the vault of the skull and the greater part of the face) by the chondrification of the skeletal matrix, the formation of which matrix is preceded by the appearance of the chorda dorsalis or notochord.

CHORDA DORSALIS or NOTOCHORD – Is a delicate semi-paque thread which appears beneath & parallel to the primitive trace or groove immediately after the formation of the latter. It forms the basis round which both the bodies of the vertebræ, and the posterior or occipito-sphenoid part of the base of the skull are subsequently developed.

Its mode of origin is still a disputed point, and its tissue-behaviour is peculiar; as are also its relations to the spinal column, the base of the skull, and the pituitary body.

Its Mode of Origin & Tissue-behaviour.

It has usually been considered as derived from the middle layer or mesoblast; and to be cellular in structure at first, but soon to become cartilaginous.

It has recently been attributed, however, on the one hand, to the under layer, or hypoblast (Hensen, Balfour), and, on the other hand, to the upper layer, or epiblast (Mihalkovics). – Modern research has certainly shown it to be structurally allied to epithelium rather than to cartilage: There is never any penetration of its substance either by connective tissue, or by blood-vessels, or by any other mesoblastic elements.

Apparently, it is not absolutely confined to vertebrata (Kowalevsky).

Its Relations to the Spinal Column, the Base of the Skull, & the Pituitary Body.

It runs first between the protovertebræ, and then through the temporary & the permanent vertebral bodies & intervertebral discs, the odontoid process of the axis, and the posterior or occipito-sphenoid portion of the base of the skull, being first swollen opposite the centre & constricted opposite the upper & lower borders of each protovertebra, and subsequently (when the protovertebræ have given place to the permanent vertebræ) swollen opposite the centre of each vertebral disc, and constricted opposite the centre of each permanent body. It is likewise swollen opposite the three intervals between the body of the axis & the odontoid process, between the odontoid process & the basi-occipital bone, and between the basi-occipital & the basi-sphenoid. – It does not pass through the anterior arch of the Atlas.

In front of the last named enlargement it curves downwards & forwards beneath the floor of the pituitary fossa, tapers to a fine filament, and is lost between the infundibulum cerebri & the hypophysis, *i.e.*, between what become respectively the anterior or glandular & the posterior or cerebral portions of the pituitary body (Mihalkovics).

THE SKELETAL MATRIX.—1st Tablet.

CRANIO-SPINAL PORTION (General View).

Is developed from the *vertebral plates* (V. General Development of the Embryo).
These plates present the following peculiarities in the (1) *Spinal,* and (2) *Cranial & Central facial portions,* respectively :

Spinal Portion.

1 – A transverse segmentation resulting in the formation of the *protovertebræ.*
2 – A longitudinal differentiation of the protovertebræ separating their *outer halves,* which become the *muscular plates* from their *inner halves,* which form the *temporary vertebral bodies,* or *protovertebral bodies.*
3 – The fusion of these inner halves.
4 – The resegmentation of these inner halves resulting in the formation of :

A – Internally – The *Permanent Vertebral Bodies, & Intervertebral discs ;*
B – Externally – The *Spinal Ganglia,* and the *Roots of the Spinal Nerves,* in front ; and the *Vertebral Laminæ & Processes* and the *Posterior Ends of the Ribs,* behind.

Cranial & Central Facial Portions.

The division, *without any previous protovertebral segmentation,* of the base of the skull opposite the two anterior swellings of the notochord into the three following portions : –

Basi-occipital }
Basi-Sphenoid }. Formed round the anterior part of the notochord by the *Investing Mass of Rathke.*

Spheno-Ethmoid * – Formed in front of the termination of the notochord from the *Trabeculæ Basis Cranii of Rathke.*

* The term *Spheno-Ethmoid* is not a good one, for it is not only the ethmoid & the anterior portion of the sphenoid which are developed from the Trabeculæ, but also the *lachrymal, nasal, intermaxillary, inferior turbinated, & vomer.* (V. Skeletal Matrix, – 4th Tablet).

THE SKELETAL MATRIX.—2nd Tablet.

THE SPINAL COLUMN.

Its evolution presents therefore for examination :—

Protovertebral Segmentation – Commences in the upper part of the cervical region before the complete closure of the medullary canal, and extends in succession through the dorsal, lumbar, sacral, & coccygeal regions. It results in the formation, on either side of the whole length of the spine, of a series of small dark quadilateral masses, the *primordial vertebræ* or *protovertebræ*, corresponding in number to the future vertebræ; of which masses, however, the first or upper ones are modified and disappear before the last or lower ones are formed.

Differentiation of the Outer Halves of the Protovertebræ forming the Muscular Plates – (Vide Development of the Organs).

Fusion of the Inner Halves of the Protovertebræ – Takes place also from before backwards, though in a somewhat less regular manner than the segmentation, and precedes the

Re-Segmentation of these Inner Halves – Vide next Tablet.

THE SKELETAL MATRIX.—3rd Tablet.

THE SPINAL COLUMN (Continued).

RE-SEGMENTATION of the INNER HALVES of the PROTO-VERTEBRÆ, RESULTING in the FORMATION of

Internally: -

THE PERMANENT VERTEBRAL BODIES, & INTERVERTEBRAL DISCS.

The lines of separation between the permanent vertebræ do not correspond to, but are on the contrary intermediate between, the primitive lines of separation between the protovertebræ. Each protovertebral body forms therefore, *anteriorly*, the posterior half of one permanent vertebral body, and, *posteriorly*, the anterior half of the following one. And, conversely, each permanent vertebral body is formed, *anteriorly*, by the posterior half of one protovertebral body, and, *posteriorly*, by the anterior half of the following one. Hence the varying position of the swellings of the chorda with respect to the spinal elements.

Externally: -

THE SPINAL GANGLIA, AND THE ROOTS OF THE SPINAL NERVES, IN FRONT; AND THE VERTEBRAL LAMINÆ & PROCESSES, AND THE POSTERIOR ENDS OF THE RIBS, BEHIND.

THE SKELETAL MATRIX.—4th Tablet.

BASE of the CRANIUM, & CENTRAL PARTS of the FACE.

The matrix of the base of the cranium is divided opposite the anterior enlargements of the chorda dorsalis into three portions, which are from behind forwards the *Basi-occipital*, the *Basi-sphenoid*, & the *Spheno-ethmoid*.

The basi-occipital & the basi-sphenoid are formed from the *Undivided Investing Mass of Rathke*. The spheno-ethmoid and the central parts of the face are formed from *Trabeculæ Basis Cranii of Rathke*.

Undivided Investing Mass of Rathke – This is a thickened deposit of mesoblastic elements thus called on account of its investing the cephalic portion of the chorda dorsalis, and of its not being affected by the protovertebral segmentation.

In the middle line it extends from the swelling of the chorda dorsalis above the apex of the odontoid process to the terminal swelling of the same a little below and behind the pituitary fossa, and supports therefore both the posterior & the middle primary encephalic vesicles.

It is opposite the swelling of the chorda intermediate between the two swellings above mentioned, that the investing mass divides into the basi-occipital, on the one hand, the basi-sphenoid, on the other.

Laterally the investing mass extends on either side of the middle line to form the matrices for the condylar portions of the occipital, for the greater wings & external pterygoid plates of the sphenoid, and for the periotic cartilage or future petrous portion of the temporal bone.

Trabeculæ Basis Cranii of Rathke – Form another and similar deposit of mesoblastic elements bifid both in front & behind, in which latter situation it embraces the pituitary fossa, while in front the two halves unite to form the septum of the nose.

In the middle line this deposit extends forwards into the frontal process (V. Development of the Face), and forms the matrices for the ethmoid, nasal, lachrymal, intermaxillary, inferior turbinated, & vomer.

Laterally it spreads out on either side of the middle line to form the matrices of the lesser wings of the sphenoid.

THE SKELETAL MATRIX — 5th Tablet.

THE REMAINDER

Is laid down in the following portions of the somatopleure :—

Segmented Portion – (Branchial, Visceral, or Pharyngeal Arches) :

Malar, Superior Maxillary & Palate Bones, and Internal Pterygoid Plates of the Sphenoid. – In superior of the two processes of first branchial arch.

Inferior Maxillary Bone & Malleus – In lower process of the same arch, the latter from back part of Meckel's cartilage.

Incus (probably)*, Stapes, Styloid Process, Lesser Cornu of Hyoid Bone – In second branchial arch.

Body & Greater Cornu of Hyoid Bone – In third branchial arch.

Unsegmented Portion ;

Shafts of the Ribs, & Lateral Halves of the Sternum.

Scapula, Clavicle, & the three Segments of Innominate Bone.

Appendicular Portions which constitute the Limbs :

Long & Short Bones of the Limbs.

* It has been said that both the Malleus & the Incus are developed from the back part of Meckel's cartilage.

CHONDRIFICATION of the SKELETAL MATRIX.

Chondrification takes place mainly during the *fifth & sixth weeks* of fœtal life.

Chondrification of the *arches of the vertebræ* commences in the dorsal region, and then spreads forwards into the cervical region, and backwards into the lumbar & sacral. No arches are formed in the coccygeal vertebræ. Those of the one or two last sacral vertebræ do not join behind.

A narrow cartilaginous band forms the sub-central portion or *anterior arch of the atlas,* which arch is quite distinct from the body & odontoid process of the axis, and out of the line of prolongation of the chorda dorsalis.

The matrices for the *posterior part of the ribs* are formed in conjunction with the vertebral arches & processes.

The bones of the *vault of the skull* and the *bones of the face* (the inferior turbinated bone excepted) are ossified in membrane.

THE DEVELOPMENT of BONE TISSUE.

There are three modes of ossification, the *intra-membranous*, the *intra-cartilaginous*, & the *sub-periosteal*.
In the two first, the process begins in, and radiates from, special fixed points termed *points or centres of ossification.*

INTRA-MEMBRANOUS OSSIFICATION — By this process are developed the bones of the *vault of the skull and all the bones of the face, except the inferior turbinated.*

In the membrane which occupies the position of the future bone, fine spicula, the *osteogenic fibres*, are seen to *radiate from the points of ossification* and to form a delicate network. These fibres are first clear and transparent, but they soon become opaque through calcification.

Large granular corpuscles, the *osteoblasts*, lie upon, and within the meshes of, the osteogenic fibres, and more or less conceal them (they must be washed away before the fibres can well be seen). These osteoblasts probably yield or secrete the substance of which the fibres are formed.

As ossification spreads, the deposit grows over the osteoblasts and incloses them. The cavities in which the osteoblasts are inclosed become the *lacunæ.*

It is not yet known whether the *canaliculi* are left as vacuities in the osseous deposit, or whether they are subsequently formed by absorption.

INTRA-CARTILAGINOUS OSSIFICATION. — By this process are developed *all the bones of the body, except* the bones of the face (the inferior turbinated excepted), and the bones of the vault of the skull.

If a *section* be made *through a point of ossification* in cartilage, and the tissues be examined from the cartilage towards the bone, *three distinct strata will be seen :* –

1. *A layer of cartilage* in which the *cells* are *rapidly increasing in number*, and are *flattened* from above downwards & arranged *one above the other* in oblong diverging groups, between which groups the matrix appears in the shape of clear diverging and obliquely intercommunicating lines. – *In the vicinity of the bone* these cells are *rounded* and greatly *increased in size*, and the groups they form are enclosed between *dark lines of ossification* which shoot up into the clear spaces of the cartilage, and form what are called the *primary areolæ.*

2. *A layer of calcified matrix*, in the primary areolæ of which the cartilage cells are replaced by granular corpuscles, or *osteoblasts*, similar to those described in the intra-membranous mode of ossification. – Whether those granular corpuscles are formed by the proliferation of the cartilage cells (Müller) or whether they are derived from the vessels of the periosteum (Sharpey), is still uncertain. Neither are their subsequent transformations clearly made out, for while they are believed by some to form the primitive marrow, the lacunæ being then developed from the cartilage cells (Kölliker, Wirchow), they are believed by others to secrete the osteogenic substance, and to form the lacunæ by becoming imbedded in the ossification.

3. *A layer of bone*, in which, by the absorption of the septa which separate them, the primary areolæ are becoming fused into larger spaces, the *secondary areolæ*, or *medullary spaces of Müller.* These secondary areolæ go on increasing in size by further absorption & coalescence, their walls becoming thickened at the same time by the deposit of new bone on their internal surface.

SUB-PERIOSTEAL OSSIFICATION — The *increase in girth* of long bones takes place by this process, which consists in the *deposit of blastema between the periosteum & the bone*, which blastema is subsequently transformed into bone by a process similar to intra-membranous ossification. – According to Kölliker & H. Müller, a *considerable portion of the shaft of long bones* is also formed by this mode of ossification, an osseous tube surrounding the primordial cartilage being developed before the ossification of the internal mass begins.

While long bones are thus increasing in girth by the deposition of new bone on their exterior, their *medullary canal* is becoming *enlarged by absorption from within.* Long bones also *increase in length* by extension of the layer of cartilage comprised between the diaphysis & the epiphysis (epiphysial cartilage) and by the progressive ossification of such layer of cartilage.

OSSIFICATION of the INDIVIDUAL BONES—V. twelve following Tablets

OSSIFICATION of the SPINE — 1st Tablet.

VERTEBRÆ GENERALLY - Developed in cartilage from *three primary centres*, and *five secondary* ones.

PRIMARY CENTRES:-

Two Lateral - For Laminæ, Processes, & Lateral Part of Body - In transverse processes; 6th week.

One Central - For Central & Greater Part of Body - Centre of body; 8th week.

Ossification from *central centres* commences about 9th or 10th dorsal vertebra, and proceeds along spine in both directions. Ossification from *lateral centres* commences at upper part of spine, and extends downwards.

Portion of body formed from *central centres* diminishes, and *portion* formed from *lateral centres* increases from below upwards: - Bodies of *sacral* vertebræ are formed almost entirely, and bodies of *lumbar* vertebræ to but a slightly less extent, from central centres. In *dorsal* region ossification from lateral centres advances to just beyond costal facets. In *cervical* region the whole lateral portions,—projecting lip at each side of upper surface, & corresponding concavity at each side of under surface,—are formed from lateral centres.

The *laminæ* are *joined to each other* during 1st year; the *arches* are *joined to the body* during 3rd year.

SECONDARY CENTRES - For:-

Tips of Spinous & Transverse Processes - One each, 16th year. - (The tip of each transverse process has sometimes two centres, but these are generally more or less united).

Upper & Under Surfaces of Body -Two, - 21st year, - for two thin circular plates thickest at circumference, of which plates the upper one is the thickest.

These secondary centres *join with remainder of the bone* about 30th year.

OSSIFICATION of the SPINE — 2nd Tablet.

ATLAS.

Two Lateral Primary Centres – In articular processes, 7th or 8th week; for lateral masses & posterior arch. – These centres correspond to the lateral centres of the other vertebræ.

The two halves of the posterior arch unite during 3rd year, their union being frequently preceded by the appearance of a *median spinal centre.*

The Atlas having no body, has *no central primary centre;* the anterior arch remains therefore as a simple band of cartilage for a considerable time. It is ossified sometimes by extension of osseous tissue from the lateral masses, at other times from either *one central or two lateral secondary centres* appearing in 1st year. When ossified separately, the anterior arch joins with the lateral masses in 5th or 6th year.

AXIS.

Three Centres for Body – Two lateral and one median; the two former appearing in 7th or 8th week for *laminæ & processes;* the latter appearing in 6th month for *lower part of body.*

Three Centres for Odontoid Process – Two lateral, & one median.

The former for *lower part* of the process, 6th or 7th month. – These centres unite before birth into a bi-lobed conical mass deeply cleft above, which joins with body during 3rd year.

The latter, for *apex*, appears at a later date in the wedge-shaped piece of cartilage which fills up the cleft (Humphry).

SEVENTH CERVICAL VERTEBRA – *Anterior part of transverse process* is developed from a *separate centre* which appears about 6th month; it joins posterior part and body between 5th & 6th years. Sometimes this portion of the bone remains separate, and, extending outwards, developes into a *cervical rib.*

The anterior part of the other cervical transverse processes is usually ossified by extension of osseous tissue from lateral primary centres. Additional centres, but appearing much later, have however been observed in the sixth & even the fifth vertebræ (Meckel).

LUMBAR VERTEBRÆ – *Two additional centres* for *tubercles on back of superior articular processes.*

The transverse process of the first lumbar vertebra is sometimes developed from a separate centre, and may then remain permanently unconnected with the rest of the bone, forming a *lumbar rib.*

OSSIFICATION of the SPINE – 3rd Tablet.

THE SACRUM – Thirty-five centres, which may be grouped as follows:–

Fifteen Primary Centres – Namely, *three for each of the five vertebræ*, as follows:

One For Body – 8th or 9th week in the three upper vertebræ, rather later in the two lower ones.

Two for Laminæ, Spinous, Posterior Transverse, & Articular Processes, and Small Portion of Body – 6th month.

Twenty Secondary Centres – Which may be grouped as follows:–

For Anterior Transverse Processes of the Three Upper Vertebræ – Three on each side, above & externally to anterior sacral foramina, 7th month.

For Upper & Under Surfaces of Bodies – Two for each vertebra, 16th year.

For Auricular Surfaces & Borders – Two on each side, 18th or 20th year.

The *bodies* are at first separated by *intervertebral discs.* These begin to ossify from below upwards about 18th year. The bodies of the two first vertebræ, however, are not united before 25th year, or later.

The *laminæ & processes* are joined to the bodies, and the several *lateral masses* to each other, also from below upwards, union taking place about 2nd year in the lower vertebræ, about 5th or 6th year in the upper ones.

The two *lateral plates* join with remainder of the bone about 25th year.

Sometimes there are separate centres for the anterior transverse processes of the two upper vertebræ only, the total number of centres being then reduced to thirty-three.

THE COCCYX – The four coccygeal vertebræ are usually developed each of them from one centre, the first one sometimes from two; ossification commencing in the

1st vertebra	- -	about the time of birth;
2nd „	- -	from 5th to 10th year;
3rd „	- -	a little before puberty;
4th „	- -	a little after puberty.

The three lower vertebræ join together before the middle of life; the second one joins with the first at a later period; and ultimately, especially in the male, the first vertebra may join with the sacrum.

OSSIFICATION of the BONES of the SKULL.

SPHENOID – Five centres for each lateral half: –

Greater Wing & Ext. Pterygoid Plate – One, between foramen ovale & foramen rotundum, [8th week.
Posterior Part of Body – One, in situation of sella turcica, a little later.
Lesser Wing & Anterior Part of Body – One, just outside optic foramen, 8th or 9th week. – Sometimes anterior part of body is ossified form a separate centre.
Internal Pterygoid Plate – One, 4th month.
Sphenoidal Turbinated Bone – One, 3rd or 4th year.

These segments unite as follows: –

THE TWO CENTRES FOR POSTERIOR PART OF BODY – 4th month.
INTERNAL PTERYGOID PLATES with EXTERNAL – 5th or 6th month.
LESSER WINGS & ANTERIOR PART OF BODY (which form together what is sometimes called the *presphenoid*) with POSTERIOR PART OF BODY – 7th or 8th month.

At birth the bone consists therefore of three separate portions, the *body & lesser wings* in the centre, and, on either side, the *greater wings & the pterygoid processes.*

GREATER WINGS with POSTERIOR PART OF BODY (forming *postsphenoid*) – 1st year.
SPHENOIDAL TURBINATED BONES with PRESPHENOID – 10th and 12th year.

Body of sphenoid joins with occipital about 18th or 20th year.

TEMPORAL – Three principal centres & several smaller ones. – Consists at first of the three following [portions: –

Squamo-Zygomatic – One centre, near root of zygoma, 7th or 8th week.
Tympanic – One, in lower part of outer wall of tympanum, 3rd month. – The tympanic portion is an imperfect ring deficient in its upper fourth, and grooved along its inner surface for attachment of membrana tympani.
Petro-Mastoid – Numerous small centres, 5th or 6th month. The first centre appears over cochlea; one or two others appear soon after over semi-circular canals. These centres soon unite, and ossification then extends into mastoid portion.

These three portions unite as follows: –

TYMPANIC & SQUAMO-ZYGOMATIC – Before birth.
SQUAMO-ZYGOMATIC & PETRO-MASTOID – 1st year.

The *external auditory meatus* deepens gradually by extension outwards of squamo-zygomatic portion, above, and of tympanic plate, below. The *Glaserian fissure* is a persistent portion of the primitive fissure between these two portions of the bone.

The *mastoid process* begins to protrude during second year; its *cells* are not formed till puberty.

The *styloid process* ossifies at puberty, but does not join with remainder of the bone till adult age is reached.

OCCIPITAL – Seven centres. – Consists at first of the four following portions: –

Tabular – Four centres, in pairs above & below occipital protuberance, 7th or 8th week.
Condylar, **Basilar** } One centre each, a few days later.

The four centres for tabular portion unite very early, forming a thin plate of bone fissured above, below, and at either side.

These three portions unite as follows: –

TABULAR & CONDYLAR – 3rd or 4th year.
CONDYLAR & BASILAR – 5th or 6th year.

The persistence of the lateral & supero-median fissures sometimes gives rise to two large symmetrical Wormian bones.

Occipital joins with body of sphenoid about 18th or 20th year.

PARIETAL – One centre, in parietal eminence, 7th or 8th week.

ETHMOID – Three centres:–

Lateral Mass – One, in orbital plate, 4th or 5th month.
Vertical & Cribriform Plates – One, 1st year.

The three segments unite about beginning of 2nd year.
The *ethmoid cells* are formed about 4th or 5th year.

FRONTAL – Two centres, one for each lateral half, in orbital arch, about 7th week.

The two halves are joined by a suture during first year, and by osseous union from below upwards, usually during the second.

OSSIFICATION of the BONES of the FACE — 1st Tablet.

LOWER JAW.

Probably * *one principal centre* for each lateral half, which centre appears early in 5th week in the fibrous tissue on outer side of cartilage of Meckel; and subsequently *four other smaller centres* for *coronoid process, condyle, angle,* and *inner side of alveolar arch.*

The two halves unite during 1st year, ossification of the symphysis taking place from below upwards.

The characteristics of the bone at birth, and for some time afterwards, are as follows:- Body shallow; ramus oblique & short; angle obtuse; coronoid process large; mental foramen near lower border.

During the development of the milk-teeth, and still more so during the development of the permanent teeth, the following changes take place:- Body increases in length, depth, & thickness; ramus lengthens also; angle becomes less obtuse; and the mental foramen further removed from the lower border: In the adult the ramus joins with the body nearly at right angles, and the mental foramen is as far removed from the lower border as it is from the upper one. Further, the curve of the alveolar arch, from being semi-circular, becomes semi-elliptical; this is due to the elongation affecting mainly the posterior part of the body, which has to accommodate the large permanent molars.

In advanced age the ramus again becomes oblique, and the angle obtuse; and the mental foramen approaches the upper border through the alveolar process becoming absorbed in consequence of the loss of the teeth.

UPPER JAW.

Probably * five centres appearing about 6th or 7th week, for
Alveolar Arch;
Palatal Portion;
Orbital & Malar Portions;
Nasal & Facial Portions;
Incisor Portion; which parts unite about end of 3rd month.

The antrum appears about 4th month as a shallow depression on inner surface of the bone; it deepens and expands in the outward direction, and separates the orbital & palate portions which are first very close to each other.

In most mammals the part which bears the incisor teeth is a separate bone, the *intermaxillary* or *premaxillary;* and for a long time in the human subject a fissure, the *incisor fissure,* may be seen to pass outwards from the incisor foramen to the alveolar border internally to canine tooth. It does not appear, however, that, even in the earliest stages, this fissure has ever been traced upon the face, or that, in the human subject, the intermaxillary portion has ever been found entirely detached from the remainder of the bone, except in bad cases of cleft palate.

Both alveolar arches present at first a groove, the *primitive dental groove* (Arnold, Goodsir) in which the tooth germs are formed (V. Development of the teeth). This groove is deepened, in the upper jaw by the down-growth of two ridges from above, in the lower jaw, by the development of a thin plate of bone on the inner surface of the body; it is then divided by partitions into separate chambers for the several tooth-sacs. The alveoli proper are formed round the fangs of the teeth as these rise to their final situation in the gums.

* The jaw-bones, first the lower one and then the upper one, are formed so very early - before any other bone except the clavicle - and so rapidly, that it is difficult to determine their primitive condition.

OSSIFICATION of the BONES of the FACE – 2nd Tablet.

PALATE – One centre, at junction of horizontal and vertical plates, 7th or 8th week.

LACHRYMAL – One centre, 8th week.

NASAL – One centre, 8th week.

VOMER – One centre, near upper border, 8th week.

From this centre two lateral plates are developed from above downwards, one on either side of the median cartilage. These plates unite gradually into one; and by the age of puberty, the ossified septum presents a mere groove on its antero-superior border.

MALAR – One centre (perhaps two, Darwin) 2nd month.

INFERIOR TURBINATED – One centre, 5th month.

HYOID – Five centres: – Three for *body* & *greater cornua* appearing about 9th month; two for *lesser cornua* appearing in 1st year.

The cornua join with the body, the greater ones towards the middle of life, the lesser ones in advanced age. – The stylo-hyoid ligaments are frequently ossified in part of their extent.

OSSIFICATION of the BONES of the THORAX.

STERNUM.

NORMAL CENTRES – Six. – One in centre of each primitive segment: –

Manubrium – One, 5th or 6th month.

Gladiolus – Four, as follows: –

First & Second Segments – One each, 6th or 7th month.
Third Segment – One, 9th month.
Fourth Segment – One, 1st or 2nd year after birth.

Ensiform Appendix – One, between 2nd and 18th years.

ADDITIONAL CENTRES – Are not unfrequently met with. Thus the

Manubrium – May have

Two centres one above the other, of which the upper one is the larger; or *three*, or sometimes *six*. – It frequently presents
Two small Episternal Centres, one on each side of interclavicular notch.

Second, Third, & Fourth Segments of Gladiolus – May have

Two Lateral Centres Each – The occasionally imperfect union of which centres may give rise to a *sternal foramen*.

The *ensiform appendix & the first segment of the gladiolus* have rarely more than one centre each.

UNION – Takes place between the above pieces as follows: –

Gladiolus – (From below upwards):

Third & Fourth Segments – Soon after puberty.
Second & Third Segments – Between 20th and 25th years.
First & Second Segments – Between 35th and 40th years.

Manubrium & Ensiform Appendix – Middle period of life.
Manubrium & Gladiolus – In very advanced age.

RIBS – Three centres each, except in case of two last.

Shaft – One, in posterior part, 7th or 8th week. – Ossification extends rapidly, and reaches situation of permanent (costal) cartilage about 4th month.

Head / **Tubercle** – One each, 16th to 20th year; join with shaft about 25th year.

The *two last ribs*, having no tubercles, are ossified, each from two centres only.

OSSIFICATION of the THORACIC and PELVIC LIMB-GIRDLES.

SCAPULA.

One Primary Centre for Body – A little behind glenoid cavity, 7th or 8th week. Soon expands into a triangular plate, from upper & back part of which the spine arises as a transverse ridge about 3rd month.

Six Secondary Centres – For

MIDDLE OF CORACOID PROCESS – 1st year; joins with remainder of the bone about 14th or 16th year.

About the same time there appear in quick succession five centres for

BASE OF CORACOID PROCESS,
BASE OF ACROMION,
LOWER ANGLE, & LOWER PART OF POSTERIOR BORDER,
TIP OF ACROMION,
REMAINDER OF POSTERIOR BORDER.

All these epiphyses join with body between 22nd & 25th years.

Another epiphysial lamina is sometimes developed in *margin of glenoid cavity.*

CLAVICLE – Vide *Long Bones with one Epiphysis.*

INNOMINATE BONE.

Three Primary Centres – For

ILIUM – A little above great sacro-sciatic notch; 8th or 9th week.
ISCHIUM – In body; 3rd month.
PUBES – In horizontal ramus; 4th or 5th month.

At birth, processes of osseous tissue have extended into the acetabulum from each of the three parts of the bone. These processes, though growing towards centre of acetabulum and towards each other, remain separated by a Y-shaped piece of cartilage till some time after 13th or 14th year, *i.e.*, for some time after appearance in this piece of cartilage of first of the secondary points of ossification.

The rami of the pubes & ischia are incompletely ossified till about 6th year; they are joined together about 7th or 8th year.

Five Secondary Centres – Appearing about 13th or 14th year, for

Y-SHAPED PIECE OF CARTILAGE AT BOTTOM OF ACETABULUM.

This piece, when ossified, connects, about 17th or 18th year, first ilium to ischium, then both the former to pubes; the ilium forming rather less than $\frac{2}{5}$ths, the ischium rather more than $\frac{2}{5}$ths, and the pubes the remaining $\frac{1}{5}$th of the acetabulum. – This Y-shaped piece is sometimes ossified from several centres.

CREST & ANTERO-INFERIOR SPINE OF ILIUM
TUBEROSITY OF ISCHIUM
SYMPHYSIS PUBIS
These epiphyses join with remainder of the bone about 25th year.

Both in the fœtus and the young child, the pelvis is much more oblique, and of much smaller capacity than it is in the adult: The bladder in both sexes, and the uterus in the female, lie partly above the brim.

OSSIFICATION of LONG BONES with TWO EPIPHYSIS— 1st Tablet

BONES OF UPPER LIMB.

HUMERUS - Seven centres, sometimes eight, - for

Shaft - 8th week.
Head - 1st or 2nd year.
Greater Tuberosity - 3rd year.

The *Lesser Tuberosity* is ossified either by extension of osseous tissue from greater tuberosity, or from a separate centre which appears in 5th year. In this same year the *centres for the head & tuberosities* are united into one epiphysis, which is joined to the shaft about 21st year.

Capitellum, & Outer Portion of Trochlea - 2nd or 3rd year.
Inner Condyle - 5th year.
Inner Portion of Trochlea - 11th or 12th year.
Outer Condyle - 13th or 14th year.

The *outer condyle & the two portions of inferior articular surface* unite to form one epiphysis, which is joined to the shaft about 16th or 17th year.

The *inner condyle* forms a separate epiphysis, which is joined to the shaft about 18th year.

RADIUS - Three centres, for

Shaft - 8th week, a little after humerus.
Lower Epiphysis - 2nd or 3rd year.
Upper Epiphysis - 5th year.

These epiphyses are joined to the shaft as follows:-

Upper Epiphysis - 17th or 18th year.
Lower Epiphysis - 20th year.

ULNA - Three centres, for

Shaft - 8th week, a little after radius.
Lower Epiphysis - For head & styloid process, 4th or 5th year.
Upper Epiphysis - For extremity of olecranon, 10th year. Coronoid process, and all but extremity of olecranon, is formed by extension of osseous tissue of shaft.

These epiphyses are joined to the shaft as follows:-

Upper Epiphysis - 16th year.
Lower Epiphysis - 20th year.

OSSIFICATION of LONG BONES with TWO EPIPHYSIS—
2nd Tablet.

BONES OF LOWER LIMB.

FEMUR – Five Centres, for

Shaft – 5th week, – before any other long bone except clavicle. – The *neck* is formed by extension of osseous tissue of shaft.
Lower Epiphysis – For condyles & tuberosities, 9th month.
Head – 1st year after birth.
Great Trochanter – 4th year.
Lesser Trochanter – 13th or 14th year.

These epiphyses & apophyses are joined to the shaft as follows:–
Lesser Trochanter – 17th year.
Greater Trochanter – 18th year.
Head – 19th year.
Lower Epiphysis – 20th year.

TIBIA – Three centres, for

Shaft – 6th week.
Upper Epiphysis – For tubercles & both tuberosities, 9th month.
Lower Epiphysis, including *Internal Malleolus* – 2nd year.

These epiphyses are joined to the shaft as follows:–
Lower Epiphysis – 20th year.
Upper Epiphysis – 25th year.
There are occasionally separate centres for *Tubercle* & *Internal Malleolus.*

FIBULA – Three centres, for

Shaft – 7th week.
Lower Epiphysis – 2nd year.
Upper Epiphysis – 4th year.

These epiphyses are joined to the shaft *in the order of their appearance:*–
Lower Epiphysis – 20th year.
Upper Epiphysis – 25th year.

OSSIFICATION of the LONG BONES with ONE EPIPHYSIS ONLY.

CLAVICLE – Two centres, for

Shaft – 5th week, before any other bone. The ossification commences before deposition of cartilage, but afterwards progresses in cartilage as well as in fibrous tissue.

Sternal End – 18th or 20th year. Joins with shaft about 25th year.

METACARPAL & METATARSAL BONES & PHALANGES – Two centres, for

Shaft – 8th or 9th week; a little later in phalanges of toes.

Distal Extremity of Four Inner Metacarpals & Four Outer Metatarsals
Proximal Extremity of Phalanges, & of 1st Metacarpal & 1st Metatarsal
} 3rd to 8th year, or a little later in phalanges of toes.

All these epiphyses unite with the shaft from 18th to 21st year.

The first metacarpal & the first metatarsal have sometimes an additional epiphysis at their distal extremity (Allen Thomson).

OSSIFICATION of the SHORT BONES.

Are all cartilaginous at birth, and are ossified as follows from one centre, except *Patella*, which has sometimes two centres placed side by side, and *Os Calcis*, which has an additional centre for its posterior & outer surfaces.

BONES of UPPER LIMB.

Os magnum – 1st year.
Unciform – 1st or 2nd year.
Cuneiform – 3rd year.
Trapezium, Semilunar – 5th year.
Scaphoid – 6th or 7th year.
Trapezoid – 7th or 8th year.
Pisiform – 12th year.

BONES of LOWER LIMB.

Os Calcis – 6th month. The additional centre appears about 10th year, and joins with remainder of the bone about 15th or 16th year.
Astragalus – 7th month.
Cuboid – 9th month.
External Cuneiform – 1st year.
Patella – 3rd year. Has sometimes two centres placed side by side.
Internal Cuneiform – 3rd year.
Middle Cuneiform – 4th year.
Scaphoid – 4th or 5th year.

TABLEAU of the OSSIFICATION of the LONG BONES.

SHAFT — One centre, from a little before middle to a little after end of 2nd month: —

Clavicle & Femur, first – 5th week.
Metacarpal, Metatarsal Bones, & Phalanges, last – 8th or 9th week.

At birth, all the shafts are ossified in the greater part of their extent.

EPIPHYSES — One centre for each, except: —

Femur – Two additional centres for *trochanters*.
Humerus – Four additional centres for *greater tuberosity, condyles, & inner portion of trochlea.*

The metacarpal & metatarsal bones (except the first) have their epiphysis at their *distal* or phalangeal extremity; the first metacarpal & first metatarsal bones and the phalanges have their epiphysis at their *proximal* extremity; the clavicle has its epiphysis at its *sternal* extremity.

Dates of Appearance of the Epiphyses.

At Birth	– Lower ep. of femur; Upper ep. of tibia.
1st Year	– Upper ep. (head) of femur; Upper ep. (head) of humerus (1st or 2nd year).
2nd Year	– Lower eps. of tibia, fibula, & radius (Radius, 2nd or 3rd year), Capitellum & outer portion of trochlea of humerus (2nd or 3rd year).
3rd Year	– Greater tuberosity of humerus;
4th Year	– Upper ep. of fibula; Greater trochanter of femur; Lower ep. of ulna (4th or 5th year).
5th Year	– Upper ep. of radius; Lesser tuberosity & inner condyle of humerus.
10th Year	– Upper ep. of ulna (tip of olecranon).
11th or 12th Y.	– Inner portion of trochlea of humerus.
13th or 14th Y.	– Lesser trochanter of femur; Outer condyle of humerus.
18th or 20th Y.	– Sternal end of clavicle.
3rd to 8th Y.	– Eps. of the metacarpal & metatarsal bones, & phalanges.

Dates of their Union with the Shaft.

16th Year	– Upper ep. of ulna.
16th or 17th Y.	– Outer condyle, & the two portions of inferior articular surface of humerus (16th or 17th year).
17th Year	– Lesser trochanter of femur.
17th or 18th Y.	– Upper ep. of radius;
18th Year	– Inner condyle of humerus. Greater trochanter of femur.
18th to 21st Y.	– Eps. of metacarpal, & metatarsal bones, & phalanges.
19th Year	– Head of femur.
20th Year	– Lower eps. of femur, radius, ulna, tibia, & fibula.
21st Year	– Upper ep. of humerus.
25th Year	– Upper eps. of tibia & fibula, & sternal end of clavicle.

In the upper limb, the epiphyses which enter into the formation of the elbow-joint, and *towards* which the respective nutrient foramina are directed, ossify later than the opposite epiphyses, but they unite earlier with the shaft. In the lower limb, the epiphyses which enter into the formation of the knee-joint, and *from* which the respective nutrient foramina are directed, ossify (except in the case of the upper epiphysis of the fibula) earlier than the opposite epiphyses, but they unite later with the shaft.

THE DEVELOPMENT of the LIMBS.

Takes place when both the axial part & the membranes have already made considerable advance, *i.e.*, in the first half of the fourth day of incubation in the chick, and about the commencement of the fourth week in the human embryo.

These appendages appear as buds from the side of the trunk, externally to the point of division of the mesoblast into splanchnopleure & somatopleure;* and they are soon seen to be formed by the somatopleure & by the epiblast. – The upper or anterior limb-bud appears a little before the lower or posterior one; and for a time it is a little more advanced in development.

Both limb-buds first develop into semicircular lappets with surfaces outer & inner (or dorsal & ventral), and borders anterior & posterior, the correspondence of which surfaces & borders with those of the future limbs is a point of considerable interest. Homologically the outer & inner (or dorsal & ventral) surfaces of the lappets correspond to each other in all vertebrates: – The outer or dorsal surface becomes the extensor surface, and the inner or ventral surface becomes the flexor surface in both upper and lower limbs; and so also do the anterior & posterior borders correspond: – the anterior border becomes what is called in comparative anatomy the *preaxial* border, and the posterior border what is called the *postaxial* border. Topographically, however, these surfaces & borders do not correspond in man & the primates, as will presently be shown.

The lappets develop mainly into the hands & feet: – Indentations demarcate the fingers & toes; the pollex and the hallux—in man & the primates, the thumb & the big toe—always being in front, or preaxial in position.

As the limbs elongate, the notch (elbow or knee) which separates the fore-arm & leg from the upper arm & thigh, appears on the ventral surface & preaxial border. Enlarged integumental folds develop at the same time at the root of each limb.

Tissue-changes complete the evolution, except as regards attitude, which latter differs in man & the primates from what it is in the lower vertebrates: – In the latter, both limbs rotate inwards: in both, the extensor surface lies in front, and the flexor surface behind; the pollex & hallux, the radius & tibia, to the inner side; and the ulna & fibula, to the outer side. In man & the primates, on the contrary, while the lower limb rotates inwards, as above, the upper limb rotates outwards: – The flexor surface of the arm and fore-arm gets to the front, and the extensor surface to the back; the thumb (pollex) & radius pass to the outer side; the ulna & little finger to the inner side. Such is the case, at least, in the conventional or *supinated* position. The upper limb of man & of the primates reverts, however, to the embryonic type in semi-pronation, and to the lower vertebrate type in complete pronation.

*At the point of division of the mesoblast there is at first a slightly elevated longitudinal ridge, sometimes called the Wolffian ridge; this ridge soon disappears, however.

DEVELOPMENT of the MUSCLES.

"The muscles of the trunk derive their origin from the muscular plates previously "referred to as being separated by differentiation of the formative cells in the outer or "superficial part of the protovertebral masses. Some difference of opinion exists, however, "among embryologists, as to how far the hypaxial (hyposkeletal of Huxley) as well as the "epaxial muscles, proceed from this source alone, or whether only the latter are traceable "to the muscular plate formed by the protovertebral differentiation, and the hypaxial may "be supposed to proceed from a deeper source."

"Recent observations seem to show that a downward extension of the mesoblast "from the protovertebræ may also give rise to the hypaxial muscles."

"Being developed from the segmented protovertebral elements, the muscular plate "shows at first the same division into segments, which are separated for a time by inter-"muscular septa (myotomes), as occurs during life in a considerable number of them in "fishes and amphibia."

"The formation of the longer muscles of the trunk proceeds from the disappear-"ance of the septa, and the longitudiual union of the fasciculi of successive myotomes. "In the trunk the direction of these remains for the most part chiefly longitudinal, but "those connected with the limb-girdles change their direction with the development of "the limb."

"The formation of the muscles of the limbs themselves has not been traced in "detail. The greater number of these muscles appear rather to arise independently in "the blastodermic tissue of the limb-bud, than to be prolonged from the sheets of trunk-"muscles (Kölliker)."

"The facial muscles, and the platysma, belong to the subcutaneous system, and are "developed along with the skin."

"The diaphragm is at first wanting. It arises soon after the formation of the lungs, "from two parts which spring from above and the sides, and which divide the pleural "and peritoneal cavities, which were previously in one, from each other."

" The muscles begin to be formed in the human embryo in the sixth and seventh "week."

DEVELOPMENT of the JOINTS.

"With regard to the formation of the joints, very little is known. It would appear "that the cavities of the synovial joints are not yet formed at the time when chondrifi-"cation has taken place in the matrix of the bones. It is therefore by a secondary "process of solution of continuity that these cavities are produced. The articular cartil-"ages remain as the coverings of the opposed surfaces of the bones, and the various "ligamentous and other parts belonging to the joints arise by processes of textural "differentiation which it is unnecessary to particularise here."

Dr. Allen Thomson's Descriptions. – QUAIN'S ANATOMY, *8th. Ed., p.p.* 744 *&* 745.

DEVELOPMENT OF THE TEETH.

DEVELOPMENT of the TEETH — 1st Tablet.

THE FIVE STAGES.

The teeth are developed from the epithelial & dermal coverings of the free edge of the alveolar arches.

The process is divided into :—

THREE PRIMARY STAGES - The

Papillary, Follicular, & Saccular (1st SACCULAR) - Completing the evolution of the *temporary, deciduous, or milk-teeth.*

A SECONDARY STAGE - The

Second Saccular - Completing the evolution of the *ten anterior permanent teeth* of each jaw, or *teeth of succession.*

A TERTIARY STAGE - The

Third Saccular - Completing the evolution of the *six posterior permanent teeth* of each jaw, or *superadded teeth.*

DEVELOPMENT of the TEETH — 2nd Tablet.

THE TEMPORARY, DECIDUOUS, OR MILK-TEETH.

THEIR EVOLUTION.

Papillary Stage – From 6th to 11th week of fœtal life.

About the 6th week of fœtal life, a groove, the *primitive dental groove* (Arnold, Goodsir), is formed along the free border of each alveolar arch.

In the situation of this groove, the layer of epithelium becomes greatly thickened, so as partly to fill up the groove with a horse-shoe-shaped process of cells, the *common enamel germ*.

In the situation of the ten future deciduous or milk-teeth, the common enamel germ sends processes downwards into the embryonic tissues, each process depressing the dermal layer.

These processes, the *special enamel germs of the ten deciduous or milk-teeth*, incline outwards and become expanded and club-shaped inferiorly, remaining connected with the common enamel germ by a narrow and somewhat tortuous pedicle.

From the bottom of the recess in which each special enamel germ is contained, an eminence or *papilla* of the derma now rises up; and, depressing the under surface of the enamel germ, becomes capped thereby.

Follicular Stage – From 10th to 14th week.

Membranous septa separate the above mentioned recesses, which now become the *dental follicles*.

Saccular Stage (1st Saccular Stage) – From 14th to 16th week.

Is marked by the closure of the dental follicles.

This closure is effected in the following manner: –

From the upper or constricted part of each follicle, small membranous processes, or *opercula*, are developed, two in number for the incisors, three for the canines, four or five for the molars. These unite and close the follicle, which now becomes a *dental sac*.

DEVELOPMENT of the TEETH — 3rd Tablet.

THE TEMPORARY, DECIDUOUS, OR MILK-TEETH.

THEIR GROWTH.

The *papilla* or *pulp* becomes moulded to the form of the future tooth.
Its superficial parts become hardened into *dentine*.
The surface of the crown is coated with *enamel* by the enamel organ; that of the fang or fangs becomes coated with *cement*.

The Pulp – The *crown* of the tooth is shaped first. A constriction round its base demarcates the *cervix*. The parts below elongate to form the *fang* or *fangs*.

The Dentine – Its DEPOSITION is as follows: – A thin cap is formed over the most prominent point of each incisor or canine, & over each cusp of the molars. These caps coalesce when there are more than one. The shell then extends over the tooth by growth round its edges, and becomes thickened at the expense of the pulp by additions from within; – the thickening continuing till nothing but a small pulp-cavity and a greatly reduced pulp remain, the latter supplied by slender vessels & nerves which enter by a minute opening at the apex of the fang.

The MINUTE HISTORY OF ITS FORMATION is as follows: – The intercellular substance of the pulp is transformed into the intertubular substance of the dentine by the deposits of nodules or globules of calcarious matter which run together into a uniform hard substance.* The dentinal tubules are left as vacuities round the radiating & ramifying processes of the more superficial odontoblasts.

* Imperfect coalescence of some of the calcarious globules between the successive strata of calcification gives rise to the *incremental lines*, *interglobular spaces*, & *granular layer of Purkinje* (Vide Structure of the Teeth—3rd Tablet). – The inner surface of the growing dentine is nodulated.

The Enamel – The *enamel organ* (Purkinje) is developed as follows from the special enamel germ of each tooth: –

The cells which line the dental sac remain flattened or cubical; those which surround the pulp (the crown—the only part as yet differentiated) become columnar & prismatic; the intermediate cells increase in number and become joined together by anastomosing caudate prolongations and by a gelatinous substance which accumulates in their interstices.

Capillary loops dip into the enamel organ from the neighbouring parts; and, on the other hand, epithelial processes are prolonged from the enamel organ into the surrounding tissues.

The enamel prisms are developed, either by deposition or by direct calcification, from the stratum of columnar cells, which cells are sometimes described as forming the *enamel membrane*.

The remainder of the enamel organ dwindles away, – the more superficial cells remaining perhaps as *Nasmyth's membrane* or the *cuticula dentis* (Vide Structures of the Teeth—4th Tablet.)

The Cement – Is developed later from a layer of blastema exsuded from the periodental membrane.

DEVELOPMENT of the TEETH — 4th Tablet.

THE TEMPORARY, DECIDUOUS, OR MILK-TEETH.

THEIR ERUPTION.

Is due to the ossification of the sockets or alveoli, to the increasing height of both crown and fang, and to the absorption of the tissues above, – the layer of bone being absorbed by the agency of the osteoclasts.

The edge of the gum becomes first dense and sharp, then rounded, tumid, of a purplish hue, and studded with a number of small white bodies at one time taken for enlarged glands, but now believed to be the epithelial process of the enamel organ above described (Sharpey).

A white point or line marks the approaching perforation of the gum.

DEVELOPMENT of the TEETH — 5th Tablet.

THE PERMANENT TEETH.

THEIR EVOLUTION.

Second Saccular Stage.

About the 14th week there appeared successively from before backwards ten lunated depressions of the posterior wall of the upper and then still patent part of each dental groove, which upper part is sometimes called the *secondary dental groove* (Goodsir).

The margins of this secondary dental groove now unite, and the lunated depressions become the *cavities of reserve*, or rudimentary follicles of the ten anterior permanent teeth, which follicles are filled, like the dental groove, with processes of epithelium.

These *follicles* elongate and recede into the substance of the gum behind the sacs of the ten deciduous or milk-teeth, – above and behind those of the upper jaw, below and behind those of the lower jaw.

A *papilla* arises from the bottom of each follicle; and *opercula* separate the lower expanding portion containing the papilla from the upper contracted and soon solidified portion, or *pedicle*.

The *dental sac* thus formed becomes surrounded by an osseous chamber, which chamber is drawn out superiorly into a canal opening upon the edge of the jaw behind the corresponding milk-tooth.

Third Saccular Stage.

The six posterior or superadded permanent teeth of each jaw are developed from the *posterior cavities of reserve*, which latter result from successive extensions backwards into the jaw of the posterior portion of the dental groove and enamel germ, *i.e.*, of that portion which lies behind the sac of the last temporary molar. From this portion, and by a process like that above described, is developed the sac of the first permanent molar. Opercula separate the lower part of this sac, and the papilla which it is soon seen to contain, from the upper part of the same; from which upper part is subsequently developed, in a similar manner, the sac of the second permanent molar. This latter sac undergoes transformations precisely similar, and from its upper part is finally developed the sac of the last permanent molar or wisdom-tooth.

THEIR GROWTH – Similar to that of the temporary teeth.

THEIR ERUPTION – The crown presses first against the bony partition which separates it from the milk-tooth and then against the fangs of the latter, and causes their absorption through the agency of the osteoclasts. This loosens the milk-tooth which falls out or is removed, and the permanent tooth rises up to take its place.

DEVELOPMENT of the TEETH – 6th Tablet.

DENTAL CHRONOLOGY.

PERIODS OF EVOLUTION.

Papillary Stage – 7th to 11th week. – The papillæ appear at about the following dates, those of the upper jaw slightly anticipating those of the lower one: –

First Molars – 7th week.
Canines – 8th week.
Central Incisors – Beginning of 9th week.
Lateral Incisors – Middle of 9th week.
Second Molars – 10th week.

Follicular Stage – 10th to 14th week. – The follicles are completed at about the following dates: –

First Molars – 10th week.
Canines – 11th week.
Central Incisors – 12th week.
Lateral Incisors – 13th week.
Second Molars – 14th week.

First Saccular Stage – 14th to 16th week.

Second Saccular Stage – The lunated depressions appear successively from before backwards about the 14th week.

Third Saccular Stage – The sacs & papillæ of the three last permanent teeth appear at about the following dates :–

First Permanent Molars – 16th week.
Second Permanent Molars – 7th month after birth.
Third Permanent Molars – 6th year after birth.

The completely developed dental sac (as seen in an infant a few months old before the eruption of the teeth) consists of (1) an *outer fibro-vascular coat* closely connected with the periodental membrane; (2) a *layer of jelly-like cellular tissue* interposed between this coat & (3) the *inner coat*, which latter is highly vascular, & lined internally with the layer of columnar cells of the enamel organ* The alveolus being imperfectly closed superiorly, the sac is continuous above with the tissues of the gum.

*In sections, a space is usually observed between these cells and the surface of the enamel; this space is believed to be produced after death by the shrinking of the soft parts.

PERIODS OF CALCIFICATION.

Temporary Teeth.

Crowns of all the Milk-teeth – About 4th month of fœtal life.
Fangs of the Same – About the time of birth.

Permanent Teeth.

First Permanent Molars – 5th or 6th month of fœtal life.
Central Permanent Incisors – 6th or 7th month „
Lateral Permanent Incisors, Canines – 8th or 9th month „
Bicuspids – 2nd year.
Second Permanent Molars – 5th or 6th year.
Third Permanent Molars, or Wisdom-Teeth – 12th year.

The permanent teeth of the lower jaw are calcified a little before those of the upper jaw. The enamel is formed shortly after the dentine, the formation commencing close to the dentinal surface. It is first soft and friable.

PERIODS OF ERUPTION.

Temporary Teeth–Appear at about the following dates, those of the lower jaw slightly anticipating those of the upper one–:

Central Incisors–7th m. after birth.
Lateral Incisors – 9th month after birth.
First Molars – 12th month after birth.
Canines – 18th month after birth.
Second Molars – 24th month after birth.

Permanent Teeth – Appear at about the following dates, those of the lower jaw slightly anticipating those of the upper one: –

First Molars – 6th year.
Central Incisors – 7th year.
Lateral Incisors – 8th year.
Anterior Bicuspids – 9th year.
Posterior Bicuspids – 10th year.
Canines – 11th to 12th year.
Second Molars – 12th to 13th year.
Third Molars – 17th to 25th year.

For a year or so before the shedding of the temporary incisors, *i.e.*, between about the 5th or 6th & 7th years, there are forty-eight calcified teeth present in the jaws, namely, all the temporary teeth, and all the permanent ones except the wisdom-teeth.

APPENDIX.

ADDENDA.

(Three Tablets removed from the Body of the Work.)

REFLEX ACTION.—3rd Tablet.

GUIDING SENSATIONS.

The influence of the will being directed towards the *result* of muscular action, and not towards the singling out of the different movements in their necessary combination and sequence, one or more "*guiding sensations*" become necessary for the accurate execution, by the automatic apparatus, of any mandate of the will. The ataxic patient who cannot feel the pressure of his foot on the ground, nor judge of the effort he is making, is, though he has really suffered no loss of muscular power, as completely unable to stand or walk as one whose limbs are actually paralysed, *unless, by looking at his feet, he supply the deficiency of his muscular sense by the visual sense.* – The same with all *sensori-motor & emotional reflex actions.*

The *muscular sense* supplies, therefore, a guiding sensation necesary for the maintenance of the standing attitude and for the performance of the ambulatory movements. – The performance of the artist, the handiwork of the artisan, the operative interference of the surgeon, etc., are all extensively guided by this sense, for "in every effort the amount of force put forth is governed by the mental conception of that which will be required, as indicated by previous experiments." (Carpenter)

The additional assistance of the *visual sense* is, however, invaluable, indispensable indeed to all those who have not been accustomed to do without it: – No one, when suddenly blindfolded, can even walk straight before him, though a blind man can do so with ease. The vertiginous movements which are caused in pigeons by the blinding of an eye (Longet) are doubtless due to the sudden suppression of the visual sense.—To some impairment of the *auditory sense* must likewise be attributed the singular jerking movements of the head induced by division of the semicircular canals (Flourens): – Division of the lateral canals induces lateral jerking movements, division of one of the vertical canals induces vertical jerking movements, and also, in rabbits, forward somersets, if the anterior canal be divided, backward somersets, if the posterior canal be divided (Cyon). – It is the auditory sense that regulates the nice adjustment of the muscles of the mouth & larynx required in vocalisation; those who are born deaf are also necessarily dumb.

Sometimes the senses may, so to speak, *contradict each other*, and disturb us rather than guide us: – Though we know we are safe, we feel insecure at the top of a tower if we look down at the precipice below; few, except the somnambulist, who is unconscious of danger, can walk along a plank laid over an abyss, unless the eye be withdrawn from below and resolutely fixed on some distant object.

The guiding sensations which regulate the performance of *habitual serial actions* may, when the mind is otherwised engaged, supply the requisite stimulus for each successive act of the series; and, in general, all movements which have been habitually performed in a particular sequence, may be kept up automatically, when the will has once set then *en train:* – An absent pedestrian finds, at the end of his reverie, that his limbs have carried him to some habitual place of resort, where, for once, he had not intended to go. – The same with regard to the operations of the mind. "If any two mental states be called up together, "or in succession, with due frequency and vividness, the subsequent production of one of "them will suffice to call up the other, and that whether we desire it or not." (Huxley)

KÜSS'S CLASSIFICATION of REFLEX ACTIONS.

Was published at so very nearly the same date as my own and so much resembles it, that I have thought it desirable, for the sake of comparison, to transcribe it *in extenso.* I may add that my first Tablet on the subject was lithographed, and was widely circulated among Students in this country (*First or Lithographed Edition of the Tablets on Physiology*, Renshaw, 1873) *nearly two years* before Professor Küss's Classification, or any account thereof, appeared in the english language, or became known to me. It is a singular coincidence that writers of two different countries should develop essentially the same idea at so nearly the same time, and in terms so nearly equivalent. – It will be observed that Professor Küss's "*Second Class*" corresponds to my "*Third Class,*" and *vice versa.*

T. C.

June 1876.

Classification of Reflex Actions. – "These are divided according to the direction "followed by the centripetal and centrifugal actions: these actions present two "directions; either the nerves of the cerebro-spinal system, or the branches of the "great sympathetic."

"The most numerous of the reflex actions follow the centripetal and centrifugal "direction of the spinal nerve filaments; of this class, the larger portion we have "already cited under deglutition, sneezing, cough, walking, etc., and in pathology a "large number of morbid reflex actions, as vomiting, tetanus, epilepsy, etc."

"A second class, almost as numerous, comprises those reflex actions where the cen-"tripetal direction is a sensory nerve of the cerebro-spinal system, and the centrifugal "direction a motor-nerve of the great sympathetic, most often a vaso-motor nerve; of "this class are the reflex actions which give rise to most of the secretions (saliva, "gastric juice, etc.), to the phenomena of blushing, or pallor of the skin, to erection, "to certain movements of the iris, to certain modifications in the pulsations of the "heart, and in pathology to a large number of phenomena called *metastatic*, on account "of the great difficulty of accounting for the mechanism of their production, as for "instance a large number of ophthalmias, of orchitis, of coryza, which depend on a "reflex hyperæmia; and, on the other hand, dependent on a reflex anæmia, as, for "instance, certain cases of amaurosis, paralyses, paraplegias, etc."

"A third class comprises those reflex actions whose centripetal action is seated in "the nerves of the sympathetic (obtuse sensibility, called *organic* in the viscera), and "whose centrifugal course is that of the cerebro-spinal motor nerves (vital relations); "most of these phenomena belong to pathology; of this class are convulsions, which "may be caused by visceral irritations produced by intestinal worms, reflex eclampsia, "hysteria etc.; as a normal phenomenon of this kind, the respiratory reflex action "may be cited, for the impression that the pulmonary surface sends to the bulb is "transmitted by the pneumogastric; which, under favorable circumstances, is brought "into relation with the nerves of the great sympathetic, or, at least, forms a physio-"logical passage between the branches of the great sympathetic and those of the "cerebro-spinal system."

"Finally, a fourth and last class can be formed of reflex actions whose ways of cen-"tripetal as well as centrifugal conduction are found in the filaments of the great sym-"pathetic; we shall have to examine at another time whether the central action for this "class is located in the masses of gray matter of the cerebro-spinal system, or in those "of the ganglions of the sympathetic chain; of this class are the obscure reflex "actions and those which preside over the secretions of the various intestinal fluids "that are still difficult of correct analysis; also those which can partially explain to "us the sympathies that unite the various phenomena of the genital functions, espe-"cially in the female; also the dilatation of the pupils from the presence of intestinal "worms in the digestive tract; and numerous reflex pathological actions analogous "to those already spoken of." – (Translated by Robert Amory, M.D., 1875.)

FURTHER REMARKS on WEBER'S VIEWS on the GENITAL DUCTS.

(A NOTE *to page* 163).

In this view, we have, opening into the female atrium, both the urethra & the vagina, and, through the vagina & its continuation, the uterus, both Müller's ducts (Fallopian tubes) and the Wolffian ducts (Gaertner's canals); and so also we have, in the male, both the urethra (the urethra proper) and the vesicula prostatica, and through the vesicula prostatica, both Müller's ducts & the Wolffian ducts, opening into what corresponds to the female atrium. And it may be remarked that this remains true whether we accept the older or the more modern view of the origin & homologies of the male excretory ducts, whether, in other terms, we consider these ducts as differentiated Müllerian ducts, or as differentiated Wolffian ducts.

This view weakens slightly, *but only very slightly, and merely as far as it is based upon homologies*, the view that, while the Fallopian tubes are differentiated Müllerian ducts, the vasa deferentia are differentiated Wolffian ducts. It weakens it in this way, namely, through abandoning the assertion that the cornua of the uterus are the continuation of the Müllerian ducts, and thus leaving open to physiologists the double alternative of considering the ducts (if any) which open into the cornua the vesicula prostatica, either as Müllerian ducts or as Wolffian ducts, and of considering the ducts which open into the sides of the vagina (Gaertner's canals) and the ducts which open into the sides of the vesicula (vasa deferentia) either as Wolffian ducts or as Müllerian ducts. But, even if arguing only from the relative position of the openings of these two latter ducts into the male & female passages respectively (V. Genital cord), we are bound to consider Gaertner's canals as Wolffian ducts and the Fallopian tubes as Müllerian ducts, and therefore to consider the ducts (if any) which open into the cornua of the vesicula as Müllerian ducts, and the vasa deferentia, which open into the sides of the vesicula, as Wolffian ducts; that is to say to adopt the more modern view.

Plantae Novae